WATER RESOURCES DEVELOPMENT PROJECT

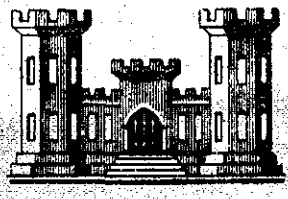
NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

PHILLIPS BROOK, MASSACHUSETTS

DESIGN MEMORANDUM NO. 2

GENERAL DESIGN



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

DECEMBER 1972

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

7 March 1973

SUBJECT: Nookagee Lake, Phillips Brook, North Nashua River Basin, Massachusetts, Design Memorandum No. 2, General Design

HQDA (DAEN-CWE-B)
WASH DC 20314

1. Reference is made to subject memorandum transmitted to your office on 22 December 1972.

2. You are requested to insert Appendix B, Recreation Resources, and Appendix E, Thermal Simulation Analysis in their appropriate places in the GDM.

FOR THE DIVISION ENGINEER:

Meyer S. Slotkin

2 Incl (14 cys)
as

MEYER S. SLOTKIN
Acting Chief, Engineering Division

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

22 December 1972

SUBJECT: Nookagee Lake, Phillips Brook, North Nashua River Basin, Massachusetts, Design Memorandum No. 2, General Design

HQDA (DAEN-CWE-B)
WASH DC 20314

1. In accordance with ER 1110-2-1150, there is submitted for review and approval Design Memorandum No. 2, General Design, for the Nookagee Lake Project. Since the memorandum was in an advanced stage of design, the contents conform to the criteria set forth in Regulation No. 1110-2-1150 dated June 1970 and does not meet all of the requirements of the new regulation dated October 1972. Noticeably, the new requirement of a Phase I and Phase II submission has not been met. The reformulation report, however, (cited in Para. 2 below) fulfills the objective of Phase I in that it provides for an "objective reassessment of the authorized project to either reaffirm the project as authorized or to modify it as required to meet changed conditions".

2. This report conforms to modifications made as a result of reformulation of the project's purposes. A description of the departures from the authorized plan and the reason for the changes are outlined in the text of the report and in the report entitled "Justification for Altering Project Purposes" dated 12 February 1971. Subsequent to submittal of the reformulation report, minimum recreational facilities and associated benefits have been added to Nookagee Lake. This represents the addition of a project purpose which was not included in the reformulation report. A detailed report on the results of the reformulation of the project has been sent to other agencies for review and comment.

3. In accordance with Paragraph No. 2 of Reference DAEN-CWE-B: Letter of Approval of Report: "Justification for Altering Project Purposes", dated 28 May 1971, the drafts of letters to the Office of Management and Budget and to Congressional Committees were forwarded to OCE on 29 July 1971.

4. Appendix B, Recreation Resources, and Appendix E, Thermal Simulation Analysis are in an advanced stage of preparation and will be forwarded for insertion within 1 month.

NEDED-E
SUBJECT: Nookagee Lake, Phillips Brook, North Nashua River Basin, Massachusetts, Design Memorandum No. 2, General Design

5. It is recommended that the project plan providing multiple-use storage for flood control, water quality control and limited recreation be approved as a basis for the preparation of detailed Design Memoranda and contract plans and specifications.

FOR THE DIVISION ENGINEER:

John Wm Leslie

JOHN WM. LESLIE
Chief, Engineering Division

Incl (14 cys)
as

WATER RESOURCES DEVELOPMENT PROJECT
North Nashua River Basin - Merrimack River
Massachusetts

DESIGN MEMORANDA INDEX

		Whitmanville Lake Whitman River			Nookagee Lake Phillips Brook		
No.	Title	Scheduled Submission	Submission	Approved	Scheduled Submission	Submission	Approved
1	*Hydrology	May 1970	7 May 1970	10 Jul 1970	May 1970	7 May 1970	10 Jul 1970
1	*Hydrology (Revised)	Jul 1971	15 Jul 1971	2 Nov 1971	Jul 1971	15 Jul 1971	2 Nov 1971
2	General Design	Jul 1971	31 Aug 1971	6 Jan 1972	Mar 1972	22 Dec 1972	
3	Public Use - Land Use Requirement Plan	(To be submitted as an appendix to GDM)					
4	Relocations	Sep 1971	24 Sep 1971	11 Jan 1972	Apr 1972		
5	Real Estate	Apr 1972	15 Sep 1972		Jul 1972		
6	*Concrete Materials	Nov 1970	26 Feb 1971	29 Mar 1971	Nov 1970	26 Feb 1971	29 Mar 1971
7	Site Geology	Dec 1970	31 Mar 1971	29 Apr 1971	Feb 1972	29 Feb 1972	17 Nov 1972
8	Embankments and Foundations	Aug 1971	20 Sep 1971	12 Jan 1972	Jul 1972		
9	Hydraulic Analysis	Mar 1973			Mar 1973		
10	**Detailed Design of Structures	Jun 1972			Sep 1973		

* Joint Submission for Both Projects

** To be completed upon receipt of construction funds

WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE

PHILLIPS BROOK

MASSACHUSETTS

DESIGN MEMORANDUM NO. 2

GENERAL DESIGN

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WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE
PHILLIPS BROOK
MASSACHUSETTS

A. PERTINENT DATA

1. Purpose — Flood Control, Water Quality Control, Recreation (Limited)

2. Location of Dam

State	Massachusetts
County	Worcester
Towns	Westminster & Ashburnham
River	Phillips Brook

Distance from:

Confluence Phillips Brook and North Nashua River	3.1 miles upstream
Confluence North Nashua and Nashua Rivers	17 miles upstream
Fitchburg, Mass.	3.6 air miles, northwest
Worcester, Mass.	23 air miles, north
Boston, Mass.	40 air miles, northwest

3. Drainage Areas

Phillips Brook at damsite	10.8 square miles
Phillips Brook at mouth, confluence with North Nashua River	15.9 square miles
North Nashua at mouth, confluence with Nashua River	132 square miles
Nashua River at mouth, confluence with Merrimack River	530 square miles
Merrimack River at mouth	5000 square miles

4. Stream Flow

Record of USGS Gaging Station on North Nashua River near Leominster, (Drainage Area - 107 square miles) September 1935 to September 1967.

Time	c.f.s.	c.f.s/square mile
Average Annual (32 Years)	188.3	1.76
Maximum Year* (1956)	307	2.87
Minimum Year* (1965)	81.2	0.76
Maximum Month (Mar. 1936)	1,289	12.05
Minimum Month (Aug. 1941)	38.1	0.36
Maximum Day (18 Mar. 1936)	7,530	70.37
Minimum Day (27 Sep. 1936)	22	0.21
Instantaneous Max. (18 Mar. 1936)	16,300	152

* Water Year, Oct. 1 through Sept. 30

5. Maximum Floods of Record

Record of USGS Gaging Station on North Nashua River near Leominster, Massachusetts.

Time	c.f.s.	Peak Discharge c.f.s./square mile
18 March 1936	16,300	152
21 Sept. 1938	10,300	96
15 Oct. 1955	8,870	83
25 June 1944	8,100	76
12 March 1936	5,500	51

6. Reservoir Elevations, Areas and Capacities

Location	Elevations Ft., msl	Area Acres	Acre Feet	Inches on Drainage Area
Streambed at Dam	750.0			
Conservation Pool	790.0	50	700	1.2
Water Quality Control Storage	816.0	190	3,000	5.2
Flood Control Storage	835.0	316	4,700	8.2
Spillway Crest	835.0	316	8,400	14.6
Maximum Surcharge	841.7			

Recreation (Limited) El. 816.0-790.0

7. Dam and Appurtenant Structures

a. Dam

Type	Rolled earth fill with rock protection
Top elevation	846.5
Top Width, Feet	25
Maximum Base Width, Feet	800
Maximum Height, Feet	105
Length, Feet	2,000
Slope, upstream above berm	1 on 3
Berm at elevation	770.0
Slope, upstream below berm	1 on 6
Slope, downstream to berm	1 on 2.5
Berm @ Elevation (between Sta. 6+70 - 15+00)	770.0
Freeboard, feet:	
above spillway design surcharge	4.8
above freeboard design surcharge	5.2

b. Spillway

Type	Uncontrolled concrete weir, "L"-Shape, side channel in rock
Crest Length, Feet	215
Effective Length, Feet	201.3
Crest Elevation, Feet, m.s.l.	835.0
Maximum surcharge, Feet	6.7
Spillway design discharge, c.f.s.	13,900

7. Dam and Appurtentant Structures (Cont'd)

c. Outlet Works

* (1) Flood Control

Type	Upstream intake tower; dry-well type and reinforced concrete, rectangular shaped, cut-and-cover conduit
Size of Conduit	3' x 5'
Length of conduit, portal to portal, feet	488
Conduit invert elevation, feet, m.s.l.	753.0
Number of Gates	
Service Gates	One
Emergency Gates	One
Size of Gates	3' x 4'
Type of Gates	Hydraulic operated vertical slide gates
Elevation gate sill, feet, m.s.l.	753.0

Discharge capacity of outlet, reservoir at spillway crest, = 470 c.f.s.

* Subject to change in design refinement.

(2) Water Quality Control

Type	Three inlets with a common standpipe discharging into the flood control conduit
Inlets	
Size of inlets	2'-6" x 3'
Elevations of inlets @ centerline	805.0, 793.0, 781.0
Number of gates	Three
Size of gates	2'-6" x 3'
Type of gates	Slide
Number of valves	Three
Size of valves	30" dia.
Type of valves	Knife gate
Standpipe	
Size	48-inch dia.
Gate (branch conduit)	1-3'x4' hydraulically operated slide gate

8. Criteria for Spillway Design Flood

Peak inflow, c.f.s.	16,500
Total volume of rainfall, inches	21.8
Infiltration rate, inches per 3-hour period	0.20
Total volume of runoff, acre-feet	11,600
Total volume of runoff, inches	20.2
Duration of storm, hours	24
Reservoir stage at start of flood, ft. m.s.l.	835.0
Gates	Closed

9. Real Estate

a. Fee Acquisition

(1) Land

Classification	Area, Acres
Agricultural	40
Residential	30
Commercial	5
Developable	30
Woodland & Cleared	492
Roads & River	23
Total Land	620

Note: An additional 16 acres of land to be acquired to provide downstream access.

(2) Improvements

Classification	Units
Residences	20
Commercial	3
Farms	3
Total Improvements	26

10. Relocations

a. Roads	Existing Mileage	Proposed Mileage
Highways	2.5	3.9
b. Utilities		
Electric Distribution lines	2.0	2.0
Telephone Exchange lines	2.8	3.0

11. Principal Quantities

Common Excavation, General	293,000 c.y.
Common Excavation, Borrow	1,160,000 c.y.
Rock Excavation, Open Cut	56,000 c.y.
Rolled Earth Embankment	1,200,000 c.y.
Gravel Bedding, Gravel Fill & Sand Fill	148,000 c.y.
Rock Slope Protection	68,000 c.y.
Concrete	5,590 c.y.
Cement	8,400 bbl.
Steel Reinforcement	330,000 lbs.

12. Estimated Project Cost (1972 Price Level)

Lands and Damages	1,500,000
Relocations	1,410,000
Reservoir	650,000
Dam and Appurtenant Structures	5,150,000
Access Road	5,000
Recreation Facilities	15,000
Buildings, Grounds and Utilities	130,000
Permanent Operating Equipment	60,000
Engineering and Design	910,000
Supervision and Administration	670,000
Total Estimated Project Cost	$10,500,000

13. Economic Analysis

Purpose	Annual Benefits	Allocated Annual Costs	Benefit/Cost Ratio
Flood Control	$ 730,000	$368,000	1.98
Recreation (Limited)	34,000	23,000	1.50
Water Quality Control	453,000	297,000	1.52
Total	$1,217,000	$688,000	1.77

14. Construction Period

Dam and reservoir and appurtenant structures	3 years

WATER RESOURCES DEVELOPMENT PROJECT

NORTH NASHUA RIVER BASIN

NOOKAGEE LAKE
PHILLIPS BROOK, MASSACHUSETTS

DESIGN MEMORANDUM NO. 2
GENERAL DESIGN
DECEMBER 1972

B. INTRODUCTION

1. Purpose. - This memorandum furnishes information and presents the general plan for the Nookagee Lake Project. It is also intended to serve as a basis for further planning and for detailed design.

2. Scope. - This memorandum presents general data for the entire project, including costs and benefits. The data contained herein will be supplemented and expanded, as required by subsequent detailed design memoranda.

C. PROJECT AUTHORIZATION

3. Authorization. - The Nookagee Lake Project was authorized by the Flood Control Act approved 7 November 1966, Public Law 89-789, which reads in part as follows:

> "The project for the North Nashua River, Massachusetts, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in Senate Document Numbered 113, Eighty-ninth Congress, at an estimated cost of $15,816,000."

Nookagee Lake, as authorized as part of the North Nashua River Plan, contained the project purposes of flood control, industrial water supply, and recreation.

4. Reformulation. - Lack of interest in the industrial water supply aspect and the obligation to include water quality control required reformulation of the North Nashua River Plan. As a result of reformulation, the purposes for Nookagee Lake were changed to include water quality control in addition to flood control. The justification for changing the project purposes (which affected both Whitmanville Lake and Nookagee Lake) was submitted as a report on 12 February 1971 and was approved as a basis for further planning on 28 May 1971. The justification report and letter of approval were included as Appendix A of the Whitmanville Lake, DM No. 2, General Design Memorandum, dated 31 August 1971.

5. Chief of Engineers Recommendations. - In Senate Document No. 113, 89th Congress, 2nd Session, the Chief of Engineers ".... concur in the views and recommendations of the Board", for which the Board of Engineers for Rivers and Harbors recommended:

" a. That the general plan for development of the North Nashua River Basin, as presented by the Division Engineer, be approved as a guide for immediate and future water resources conservation;

b. That four of the reservoirs namely, Whitmanville, Nookagee, Phillips, and Monoosnoc, and the three local-protection projects be authorized for construction in the interest of flood control, water supply, recreation, and other purposes generally in accordance with the plan of the Division Engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated first cost of $16,090,000, of which $15,503,500 would be Federal and $586,500 would be non-Federal, and at an estimated average annual cost for maintenance and operation of $59,600, of which $20,200 would be Federal and $39,400 non-Federal, prior to reimbursement for water supply, and that any element of the plan may be undertaken independently of the others whenever funds for that purpose are available and the prescribed local cooperation has been furnished;

c. That immediately following authorization of the four reservoir projects, detailed site investigation and design be made for the purpose of accurately defining the project lands required; that subsequently advance acquisition be made of such title to

such lands as may be required to preserve the sites against incompatible developments; and that the Chief of Engineers be authorized to participate in the construction or reconstruction of transportation and utility facilities in advance of project construction, as required to preserve such areas from encroachment and avoid increased costs for relocations;

d. That prior to construction of the Whitmanville, Nookagee, Phillips, and Monoosnoc reservoir projects, responsible non-Federal interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Repay all the costs allocated to water supply, as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended, presently estimated as follows:

Reservoirs	Apportioned initial construction cost for water supply		Annual operation, maintenance and major replacements	
	Percent	Amount	Percent	Amount
Whitmanville	29.4	$1,130,000	38.3	$2,300
Nookagee	36.5	$1,980,000	11.0	$2,200
Monoosnoc	27.6	$ 720,000	9.5	$1,600

(2) . . .

(3) Protect channels downstream of the reservoirs from encroachments which would adversely affect operation of the system;

(4) Hold and save the United States free from all damages due to water-rights claims resulting from construction and operation of the reservoirs; and

(5) Exercise to the full extent of their legal capability, control against removal of water in the basin which will affect the reservoir's water supply storage and the development of dependable stream regulations." (*Note: These requirements have subsequently* been modified due to project reformulation - See Para. 51 - Project Reformulation).

D. INVESTIGATIONS

6. Latest Interim Report. - The interim report on review of survey for flood control and allied purposes, Merrimack River Basin, North Nashua River, Massachusetts, dated 25 January 1965 contains the report on Nookagee Lake. The report was published without appendicies, except letters of comment, in Senate Document No. 113, 89th Congress, 2nd Session. The preparation of the report was authorized by resolution of the Senate Commitee on Public Works on 9 February 1961. The report recommended that the water resources plan for the North Nashua River Basin be authorized to provide seven reservoirs and three local protection projects. Further, the report recommended that four of the reservoirs, designated as Nookagee, Whitmanville, Phillips, and Monoosnoc, and three local protection projects be authorized for immediate construction for the purposes of flood control, water supply, recreation, and fish and wildlife conservation as applicable. The report provided for construction of a multiple-purpose project on Phillips Brook to include 4,700 acre-feet for flood control, 2,600 acre-feet for industrial water supply and 800 acre-feet for recreation with the total capacity equivalent to 13.8 inches of runoff from its net drainage area of 11.0 square miles. The site is in the towns of Westminster and Ashburnham and is about 3.1 miles upstream from the confluence of Phillips Brook and the North Nashua River.

7. Prior Reports. - Flood control in the North Nashua River and its tributaries has been considered in the following published reports on the Merrimack River Basin.

a. "308" Report. - The Merrimack River in New Hampshire and Massachusetts was studied by the Corps of Engineers under provisions of House Document No. 308, 69th Congress, 1st Session, which was enacted into law with modifications in Section 1 of the River and Harbor Act of 21 January 1927. The reports prepared became known as the "308" Reports. The Merrimack River report was published as House Document No. 649, 71st Congress, 3rd Session.

b. 1938 Survey Report for Flood Control. - Following the disastrous flood of March 1936, a report for the Merrimack River

Basin was submitted and published as House Document 689, 75th Congress. The report recommended modification of the existing project, adopted in the Flood Control Act of 1936, and to provide for the construction of a system of flood control reservoirs and related flood control works which may be found necessary by the Chief of Engineers. This system was authorized by the 1938 Flood Control Act and included four reservoirs and local protection projects at five locations being:

Project Dams and Lakes	Present Status	Year Completed
Blackwater Dam	Completed	1941
Edward MacDowell Dam	Completed	1950
Franklin Falls Dam	Completed	1943
Hopkinton-Everett Lakes	Completed	1962
Local Protection		
Fitchburg	Completed	1937
Haverhill	Completed	1938
North Andover & Lawrence	Inactive	-
Lowell	Completed	1944
Nashua	Completed	1948

c. NENYIAC Report. - The report of the New England-New York Inter-Agency Committee (NENYIAC) considered all aspects of the land and water resources of the area. The report was published as Senate Document No. 14, 85th Congress, 1st Session. Chapter XV of Part Two of the report covers the Merrimack River Basin in New Hampshire and Massachusetts. The NENYIAC Report considered the problem of flood control and determined that there was need for additional flood control measures in the basin.

8. Studies in Progress. -

a. The North Atlantic Regional Water Resources Study. - The NAR Study is one of 20 regional comprehensive water and related land resources studies conducted throughout the United States under

guidelines established by the Water Recources Council. The NAR study was authorized by the 1965 Flood Control Act (Section 208, Public Law 89-298). The study's objective was to establish a broad master plan or framework to serve as a basis for future regional water resources development and management. The requirements and needs of the people of the region were considered in analyzing water resource needs including water quality control, flood control, municipal and industrial water supply, irrigation and rural water supply, navigation, hydroelectric power, recreation, fish and wildlife and other environmental resources. These needs were projected through the year 2020. The study began in 1969 and was completed in 1972.

b. Northeastern United States Water Supply Study (NEWS). - The unprecedented drought that started in 1960 over the northeastern seaboard of the Nation, led Congress to authorize the Secretary of the Army, in October 1965 (Public Law 89-298), to cooperate with Federal, State, and local agencies in preparing plans to meet the long-range water needs of the Northeastern United States. It anticipated that such plans may include major reservoirs, major conveyance facilities to transfer water between river basins, and major purification facilities to be constructed under Federal auspices with appropriate non-Federal financial participation. The water supply study was initiated in 1966 and is scheduled for completion in FY1974. Utilization of existing polluted water resources to help meet the water supply needs of the metropolitan centers of the Northeast is being investigated under the Merrimack Wastewater Study. This wastewater study is similarly being conducted under the authority of Public Law 89-298 and is one of 5 such feasibility studies being made throughout the nation. These pilot studies are being carried out by the Corps of Engineers under a cooperative agreement between the Department of the Army and the Environmental Protection Agency. The first phase (Feasibility) of the Merrimack Wastewater Study was completed in September 1971. The second phase of study (Survey and Scope) is presently under way and is scheduled to be completed in late 1973.

9. Current Investigations. - Studies for the project plan utilized the basic data obtained for the previous investigations. In addition, the following new data were obtained and studies made:

a. New photogrammetric maps of the reservoir area were made and new area capacity curves computed. A new large scale topographic survey map of the damsite was prepared.

b. All available subsurface information has been reviewed and the geological and soils investigations of foundation conditions and embankment materials are being completed.

c. Hydrologic studies have been reviewed and new studies have been made to determine the reservoir capacity, the spillway design flood and outlet requirements. The DM on Hydrology (Revised) was prepared and submitted to the Chief of Engineers and was approved in November 1971.

d. New preliminary appraisals of lands and damages to improvements in the reservoir, work and borrow areas have been completed and are reported in Section U of this Memorandum.

e. Relocation of roads within the reservoir has been discussed with State, County, and Town officials. Preliminary studies of the affected roads have been made.

f. Relocations of utilities have been discussed with the owners and preliminary studies have been prepared.

10. Coordination with Other Federal and Non-Federal Agencies. -

a. Federal Power Commission. - During the preparation of the interim report of January 1965, the Federal Power Commission reviewed the power potentialities of the six proposed multiple-purpose reservoir projects on the North Nashua River tributaries. The Commission concluded that none of the six proposed reservoir projects are adapted to practicable and economic development of hydroelectric power in conjunction with other project purposes. The views of the Federal Power Commission were confirmed in letter dated 30 January 1964, which is included in Appendix C of this Memorandum.

b. U. S. Department of Health, Education and Welfare. - During the review of the 1965 Survey Report of the North Nashua River Basin, the Department of Health, Education and Welfare pointed out the need for providing in these projects storage for water quality

control to supplement the waste treatment program. HEW stated that studies were then being made by their Office to determine the level of waste treatment to be required of industries and municipalities in the basin and the studies would be followed by establishment of a schedule for abatement. Upon establishing the abatement schedule, HEW intended to make firm projections of need for storage for water quality control and intended to provide this information to this Office upon completion.

During the study of the water quality needs, the Federal Water Pollution Control Administration was transferred from HEW to the Department of the Interior. While under the Department of the Interior, the Northeast Region of FWPCA prepared and submitted to the New England Division in April 1968 a report entitled "Water Quality Control Study, North Nashua River Basin, Massachusetts".

Although the primary responsibility for water quality no longer remains with HEW, coordination with HEW with respect to health hazards has been pursued. Comments on the reformulation of the Nookagee and Whitmanville Lake projects were requested from HEW.

c. The Environmental Protection Agency. - With further reorganization, the FWPCA became the Water Quality Office (WQO) under the Environmental Protection Agency. NED has maintained close coordination with the Regional Office. As stated in Paragraph 4 (Page 2) of Appendix A of the Whitmanville DM No. 2, the WQO did update the minimum flow requirements based upon a more critical reach of the river. A detailed report on the results of the reformulation of the projects was sent to the Water Quality Office of the Environmental Protection Agency for review and comments. Comments received have been included as Exhibit C-3.

d. Commonwealth of Massachusetts, Water Resources Commission. - During the review of the Survey Report on the North Nashua River, the Water Resources Commission on behalf of the Commonwealth of Massachusetts expressed a vital interest in the multiple-purpose development proposed by the New England Division and would support "any State legislation necessary to carry out the local requirement of the project" - Appendix C, Exhibit C-5. During

the period of reformulation, the Water Resources Commission reaffirmed its strong interest in the projects and specifically the need for inclusion of water quality storage - Exhibit C-7. Comments on the reformulation were requested from the Commission. Response to the reformulation was received from the Governor by letter dated 23 July 1971 (Exhibit C-6).

e. Coordination with Other Federal and State Agencies. - Comments on the reformulation of the Nookagee Lake project as well as the Whitmanville Lake project were requested from the following agencies:

Federal:

Office of Water Hygiene, EPA
Department of Housing and Urban Development
Federal Highway Administration
Department of the Interior (Fish and Wildlife Service)

State:

Division of Environmental Health
Division of Fisheries and Game
Department of Natural Resources
Water Pollution Control Division
Department of Public Works

Regional:

New England Interstate Water Pollution Control Commission
New England River Basins Commission
New England Regional Commission
Montachusett Regional Planning Commission

The comments received are included in Appendix C.

11. Public Hearings. -

a. Survey Report. - A public hearing was held on 13 November 1962 in Fitchburg, Massachusetts, to determine the need for additional projects for flood control and allied purposes on the North

Nashua River, Merrimack River Basin. Improvements requested by representatives of Federal, State, and municipal governments included flood control dams and reservoirs and various local improvements.

b. Recent Hearings. -

(1) On 17 July 1969, an open information type meeting was held in Westminster, Massachusetts. Approximately 50 local and Fitchburg residents as well as conservation and planning board members attended. The meeting afforded an opportunity to review the Nookagee and Whitmanville Lakes project features and purposes, discuss the effect of withdrawal of support for the industrial water supply purposes, and discuss future planning. The hearing was well received and the attendees expressed interest in the projects and, in particular, the recreational aspects. No expressions of opposition to the projects were voiced at the meeting.

(2) A second special open information type meeting was held on 7 December 1971 in Westminster, Massachusetts at the request of Selectmen of the Town of Westminster. The meeting attracted approximately 50 residents of the Town who were directly or indirectly affected by either the Nookagee or Whitmanville Lake projects. The majority of those making statements expressed opposition to the projects. Subsequent to the meeting, those opposing the projects were instrumental in having a resolution passed at the annual town meeting placing the Town in opposition to the projects. The reaction by the Town is similar to the reaction of other communities faced with imposition of projects in their midst. Loss of homes and taxes in their town, while other towns benefit, is an understandable concern on the part of the inhabitants. Representatives from NED and the State have attempted to show the Town officials and the concerned citizens that many of their fears are unfounded. Comments from the Selectmen and the Corps response to the comments are included in Appendix C.

E. LOCAL COOPERATION

12. Recreation (Limited). - During reformulation of the projects, the Whitmanville Lake site was found to be the more suitable site for extensive recreation development. The Whitmanville site offered the primary advantages of a stable pool, a more interesting shoreline, and more suitable land for development. In reviewing the reformulation report, OCE recommended that minimal facilities be provided at the Nookagee site. NED, along with the U. S. Fish and Wildlife Service and the Commonwealth of Massachusetts, agreed that minimal recreational facilities should be provided at the site. It was further agreed by all three parties that the facilities should be oriented along the primary interest of fishing. The report by the U. S. Fish and Wildlife Service, Appendix A, defines the fishing potential of the lake and the stream below the damsite. Corps personnel have met with representatives from the Service and the State to review the report. Both agencies were informed that the Corps agreed with the report and also agreed with the recommendations with minor exceptions. The Service's recommendation to mitigate the loss of 2 miles of stream fishing by "opening up" the 2 mile reach of the stream below the damsite is considered reasonable (actual loss is 1-3/4 miles). An investigation is presently being made to determine the feasibility of obtaining easements along the stream to the extent recommended. Acquisition of land along the stream will be made only if easements cannot be obtained and if it is deemed essential to the downstream plan. A more detailed discussion on the report is included in Appendix "B" Public Use-Land Use Requirement Plan. The representative from the State indicated that the State would not (due to drawdown and financial considerations) participate in any extensive development at the site and consequently recommended that minimal facilities be provided. The U. S. Fish and Wildlife Service concluded that the minimal development concept, would still provide the amount of benefits listed in their report. On the local level, strong interest in the recreational developments has been expressed by the Cities of Fitchburg and Leominster.

13. Flood Control & Water Quality Control. - Based upon reformulation of the projects (See Para. 51, Project Reformulation), and as modified by Comment 19 of 1st Indorsement to Whitmanville Lake DM No. 2, local interests are required to: (1) protect channels downstream from encroachment, and (2) control against removal of water in the basin. Flood control and water quality control benefits

are widespread and their costs are considered entirely Federal. Efforts on a local and regional basis (See Paragraph 32) demonstrate the seriousness and determination inhabitants of the basin have in cleaning up the pollution and in protecting the natural resources. Strong support for the flood control and water quality control aspects has been expressed by the City of Fitchburg (Exhibit C-10) and by the Commonwealth of Massachusetts (Exhibit C-5 of Appendix C). Protection of the channels from encroachment is being actively pursued by numerous cities and towns along the North Nashua and Nashua River. The cities of Fitchburg and Leominster have filed requests with the Corps for flood plain management studies. The City of Nashua, New Hampshire is in the midst of rezoning which includes an ordinance for flood plain zoning. The Town of Pepperell has passed flood plain zoning by-laws. The Montachusett Regional Planning Commission has taken the position that flood plain zoning in downstream communities should be required prior to construction of the flood control projects.

F. LOCATION OF PROJECT AND TRIBUTARY AREA

14. Location of Project. - The Nookagee Lake Project is located on Phillips Brook in the Towns of Westminster and Ashburnham, Massachusetts (Plate 2-1). Phillips Brook has its source in Winnekeag Lake (El. 1,126 m.s.l.) in the Town of Ashburnham and flows in a southerly direction for eight miles to its confluence with the North Nashua River. It has a drainage area of 15.9 square miles and a total fall of about 600 feet. The damsite is about 3.1 miles above the confluence of Phillips Brook with the North Nashua River. The lake will extend upstream about 1.4 miles and control a drainage area at the damsite of 10.8 square miles.

15. Description of the North Nashua River Basin. - The North Nashua River Basin is situated in north-central Massachusetts in the northern portion of Worcester County. The basin encompasses three cities and seven towns lying wholly or partially within the basin. The largest urban area, Fitchburg-Leominster, is one of ten Standard Metropolitan Statistical Areas (SMSA) in Massachusetts and constitutes the major population center within the basin. The area is about 40 miles from Boston and 25 miles from Worcester.

The North Nashua River is formed at the confluence of the Whitman River with Flagg Brook in the city of Fitchburg, Worcester County, Massachusetts, at an elevation of 590 feet above mean sea level and has a total fall of 365 feet over its 18.2 miles of length. The river pursues a generally northeasterly course for about three miles into the center of Fitchburg and then turns to a generally southeasterly course for about eight miles to the USGS gage in Leominster, and thence seven miles to its confluence with the Nashua River in the town of Lancaster. The 132 square mile watershed of the North Nashua River, contributes to the Nashua River drainage area of 530 square miles, and in turn contributes to the Merrimack River drainage area of about 5,000 square miles.

G. RECOMMENDED PROJECT PLAN

16. Recommended Project Plan. - The recommended project plan provides for a rolled earthfill dam with rock protection, 2,000 feet long and 105 feet in height above the stream bed (Plates 2-2 and 2-3). An "L"-shape side channel spillway with a 215-foot uncontrolled concrete weir will be located in a rock cut in the left abutment with the spillway crest at elevation 835.0. The outlet works will consist of a 3-foot by 5-foot cut-and-cover concrete conduit founded on earth in the right abutment of the dam.

Ashburnham Street, a two-lane bituminous surface State road (Route 12) which runs adjacent to the brook, will require relocating and raising above the guide taking line, a total of about 1.5 miles. The intersection of roads; Dean Hill, Fred Smith, Sheldon and McIntire with the new Ashburnham Street will be modified to provide a smooth and safe transition for traffic. Dean Hill, Fred Smith and Bean Porridge Hill Roads will become "dead end" in the vicinity of the reservoir. The existing Ashburnham Street will be truncated just below the dam and a turnaround provided. A connecting road (Spur Road) will be provided between the truncated Ashburnham Street and Bean Porridge Hill Road. The connecting road will serve as the main route for school busses and fire apparatus servicing the northeastly segment of the town and the road will also provide access to the top of the dam. Presently, the

primary route for Town service vehicles, located in the western part of the Town, is by way of Bean Porridge Hill Road. Potato Hill Road was determined to be unacceptable as a service road due to its steep grades (11 to 13%).

Electric and telephone lines will be relocated along the relocated road. No water lines are required to be relocated.

The structures, improvements, and relocations are described in detail in Section M - Description of Proposed Structures and Improvements. The various structures and topography at the site, and proposed alignment of road relocations are shown in Plates 2-2 and 2-3.

H. DEPARTURE FROM PROJECT DOCUMENT PLAN

17. Project Document Plan. - The Nookagee Lake Project, along with the Whitmanville Lake, Monoosnoc Lake and Phillips Dam, was authorized by the Flood Control Act of 7 November 1966 substantially in accordance with Senate Document No. 113, 89th Congress, 2nd Session. The plan proposed that the Nookagee project be authorized with flood control, industrial water supply, and recreation as project purposes. The flood protection would consist of 4,700 acre-feet, equivalent to 8.0-inches of runoff from a drainage area of 11.0 square miles. The industrial water supply storage was to consist of 2,600 acre-feet (4.4-inches of runoff) and 800 acre-feet (1.4-inches of runoff) was to be allocated for recreation. Using topographical data derived from USGS quadrangle sheets, the required capacity set the spillway crest elevation at 835 feet m.s.l.

18. Departure from Project Document Plan. -

a. Reformulation. - As a result of the reformulation of Nookagee Lake, as stated in Section O,- Project Reformulation and Evaluation, the approved changes to the project include:

(1) Deletion of the industrial water purpose,
(2) Inclusion of 3,000 acre-feet of storage for low flow augmentation for water quality control, and

(3) Transfer of the main recreational development from the Nookagee site to the Whitmanville site. Recreational development for Nookagee Lake is to be limited and will consist of basic minimal facilities.

b. Planning and Design. - In addition to changes in project purposes for Nookagee as stated above, the following modifications and changes from the authorized document plan have been made based upon development of detailed planning and design studies.

(1) The area capacity curves developed from the new plane table maps of the reservoir indicated that for full pool (Elevation 835.0) the storage volume was 300 acre-feet (4%) greater than that determined in the survey report. The contributing drainage area was found to be 10.8 square miles rather than 11.0 square miles.

(2) The top elevation of the dam has been lowered from elevation 848.0 to 846.5 m.s.l., due to the combined effort of changes in the spillway design flood inflow hydrograph, crest length and discharge coefficients.

(3) The outlet controls have been changed from two independent works to a single-multi-purpose outlet works; due to changes in project purposes and for economic reasons.

(4) Economic studies of spillways of various lengths indicated that an "L"-Shape side channel spillway of 215-foot length should be adopted.

(5) A climbing land (1.6 miles in length) has been added to the relocated segment of Route 12 to meet the minimum road standards of the State.

(6) The access road to the top of the dam has been modified. A connecting road (spur road) between the truncated segment of Ashburnham Street and Bean Porridge Hill Road was added for reasons previously stated in Section G. Access to the top of the dam will be by way of the connecting road.

(7) Subsurface explorations have indicated that an impervious blanket should be added upstream of the dam to minimize seepage and to reduce uplift pressures on the embankment.

(8) The centerline of dam was moved in a southerly direction from the alignment selected in the 1965 report. At the east abutment, the alignment was moved 100 feet south and at the west abutment it was adjusted approximately 150 feet south. The change in alignment was based upon more accurate survey data, field reconnaissance and on subsurface explorations.

(9) An Overlook Area has been added adjacent to the relocated Route 12 at a point east of the damsite.

I. HYDROLOGY & HYDRAULICS

19. Reservoir Capacity. - Flood control reservoirs in New England, built by the Corps of Engineers, generally have capacities equivalent to 6 to 8-inches of runoff from the contributing drainage areas. The exact amount of storage is dependent on the geographic location of the reservoir and physical limitations at the site. This amount of storage is required for effective control of the Standard Project Flood and also for control of floods, the magnitude of such historical events as the November 1927, March 1936, September 1938, and more recently the October 1955 flood.

The hydrologic characteristics of the watershed dictated that at least 8-inches of flood storage be recommended for authorization. Since the Whitmanville Lake Project contains seasonal encroachment on the flood control pool, there is added significance in providing 8-inches of storage at Nookagee on a year round basis. Based on more detailed photogrammetric mapping, the recalculated drainage area for the Nookagee Lake Project was found to be 10.8 square miles instead of 11.0 square miles estimated in the survey report. The decrease in the estimated contributing drainage area will provide an actual flood control storage equivalent to 8.2-inches of runoff.

Natural discharge frequency curves at index stations on the North Nashua River were presented in Design Memorandum No. 1,

Hydrology (Revised), dated July 1971. The Whitmanville and Nookagee projects will reduce floodflows on the North Nashua in Fitchburg generally by about 55-percent. Similarly, floodflows will be reduced at the USGS gage in Leominster by about 40-percent.

Following the record 1936 and 1938 floods, high water elevations along the North Nashua were recorded and this data was published by the U. S. Geological Survey. Profiles of these floods were shown in: "Water Resource Development Plan, North Nashua River Basin," Appendix C, dated 25 January 1965. In a recurrence of these record floods, the reservoirs would generally reduce flood stages from 2 to 4 feet through Fitchburg and Leominster. Reductions would become progressively less downstream with a reduction of about 0.5-foot on the Nashua River at East Pepperell and about 0.3-foot at Nashua, New Hampshire.

20. Spillway Design Flood. - The spillway design storm was based on the probable maximum precipitation over a 10.8 square mile drainage area. The depth of rainfall over the Phillips Brook watershed upstream of the damsite totaled 21.8-inches. Losses were assumed at a rate of 0.2-inches per three-hour period resulting in a rainfall excess of 20.2-inches. The rainfall excess values were applied to the adopted unit hydrograph for 7.9 square miles of land area. To this was added the direct rainfall on the reservoir itself plus the routed outflow from Winnekeag Lake resulting in an inflow hydrograph with a peak of 16,500 c.f.s. With a spillway length of 215 feet (effective length of 201.3 feet) and discharge coefficient varying with head, the spillway design flood hydrograph was routed through the reservoir. The flood was routed assuming two starting elevations: (a) reservoir at 50% flood control capacity (El. 826.6), and (b) reservoir at spillway crest El. 835.0. For both conditions, the flood control conduit outlet was assumed inoperative. For the selected spillway length of 215 feet, the resulting surcharges for the two conditions stated above were 6.3 and 6.7 feet, respectively.

21. Freeboard and Top of Dam. - In accordance with EC 1110-2-27 a freeboard of 5.0 feet was allowed for the above condition (a) and 3.0 feet was allowed for condition (b). The top of dam required for condition (a) was determined to be 846.3 and for (b) 844.7. The adopted elevation for the top of dam was 846.5. The design spillway discharge was determined to be 13,900 c.f.s.

Summarized:	Case (a)	Case (b)
Reservoir elevation at start of flood	826.6	835.0
Spillway crest elevation (m.s.l.)	835.0	835.0
Surcharge (feet)	6.3	6.7
Minimum freeboard (feet) Top of Dam	5.0	3.0
	846.3	844.7

Selected Top of Dam: 846.5

22. Outlets. - The outlet works for Nookagee Lake will consist of a gated intake tower with a primary flood control outlet at the bottom and a secondary tri-level outlet to permit selective withdrawal of water quality releases.

A 3 x 5-foot conduit was selected as the primary outlet to handle (a) normal stream flows, (b) pass discharges for regulation of the reservoir during floods, (c) permit evacuation of the flood storage within a reasonable period of time and (d) pass a flood of reasonable size during construction. This conduit will have a capacity of approximately 413 c.f.s. with the pool at 816.0 and 470 c.f.s. with full pool.

The selective withdrawal outlet system was designed with the aid of the thermal simulation and density current analyses which are reported in Appendix E of this Design Memorandum. Each outlet has the capacity to discharge the range of flows up to 110 c.f.s. (10 c.s.m.) with the pool at elevation 816.0 feet m.s.l. This capacity provides capability to control the quality of releases made during those minor flood events (up to 5 year recurrence interval), which would encroach on the flood control storage but do not materially upset reservoir stratification.

23. Channel Capacity. - The non-damaging channel capacity of Phillips Brook, downstream of the dam, is estimated to be 300 c.f.s.

24. Supplemental Presentations. - Hydrologic analysis for the subject Whitmanville and Nookagee Projects was presented in greater detail in DM No. 1, Hydrology (Revised). Detailed hydraulic analysis will be presented in DM No, 9 to be submitted at a later date.

The minimum guide taking elevation was selected at 840.0 feet m.s.l., 5 feet above spillway crest. This guide taking elevation will provide a high degree of protection against flood damage to non-Federal property surrounding the Lake. The minimum guide taking line was further governed by the minimum horizontal distance requirement as defined in Section U.

Sedimentation of water bodies in New England,is insignificant; consequently, a sedimentation analysis was not performed. Existing lakes and reservoirs in the watershed substantiate this conclusion. The influence of the reservoir on the groundwater levels is expected to have only a minimal effect within the close proximity of the pool. The "tightness" of the reservoir and the elevations of the subsurface water are discussed in Paragraphs 9 and 10 of DM No. 7, Site Geology.

J. WATER QUALITY CONTROL

25. General. - Serious pollution exists in the North Nashua River from the mouth of the Whitman River in Fitchburg to the confluence of the North and South Branches of the Nashua River at Lancaster. Discharges from the paper mills and sewage treatment plants, particularly at Fitchburg and Leominster, contribute to the problem by causing high bacterial densities with suspended solids, nutrients, and organic matter which increase biochemical oxygen demand. The waste discharges far exceed the assimilative capacity of the stream. As a consequence, the water quality is badly degraded, resulting in obnoxious and nuisance conditions. The tributary flows upstream of the waste discharges are generally of excellent quality and a good environment for biological life.

26. Comprehensive Water Quality Control Study. - At the request of the Corps of Engineers, the Water Quality Office of the Environmental Protection Agency investigated the need for regulations of streamflow for water quality purposes in the North Nashua River Basin. Their conclusions were published in a report dated April 1968 entitled "Water Quality Control Study, North Nashua River Basin", and summarized the water quality problem as:

a. The North Nashua River is in a nuisance condition below Snows Mill Pond, mainly due to industrial and municipal pollution

arising in Fitchburg and Leominster. Allowing for industrial and population growth, it is foreseen that water quality will not meet standards set by the Commonwealth of Massachusetts even if all waste received a high degree of treatment at its source.

b. Flow in the North Nashua River Basin is now regulated privately for industrial water supply purposes. Additional low flow regulation by the authorized reservoirs for purposes other than water supply would in conjunction with adequate treatment of wastes at their source and continued regulation of existing reservoirs, result in meeting the approved state standards and in maintaining a suitable water quality for the foreseeable future.

c. Benefits due to the improved quality would be widespread and of major economic significance to the entire region. They would include enhanced real estate values, an improved acquatic environment, enhanced recreational opportunities and an upgrading of the general economy of the region.

d. Facilities sufficient to maintain minimum flow requirements, should be incorporated in the water resources development plan for the North Nashua River Basin.

27. Water Quality Standards. - Water quality standards, as recommended by the Massachusetts Division of Water Pollution Control and as approved by the Massachusetts Water Resources Commission, and the Secretary of the Interior, have been established for the North Nashua River. These standards require that: (a) secondary treatment, or its industrial waste equivalent, be provided for all wastes on the North Nashua River; (b) that certain watersheds designated for water supply shall meet Class A criteria; (c) that all other tributaries shall meet at least Class B criteria; and (d) that the main stem of the North Nashua shall conform to Class C criteria. Class C requires a dissolved oxygen content of not less than 5 mg/l during at least 16 hours of any 24-hour period nor less than 3 mg/l at any time. Complete data on classification criteria of the Commonwealth of Massachusetts were included in Appendix B of the Whitmanville GDM and classification locations in the North Nashua Basin are shown on Figure 1.

28. Future Waste Loading. - Future waste loadings in the years of 2020 and 2070 are expected to be geographically similar to that of the

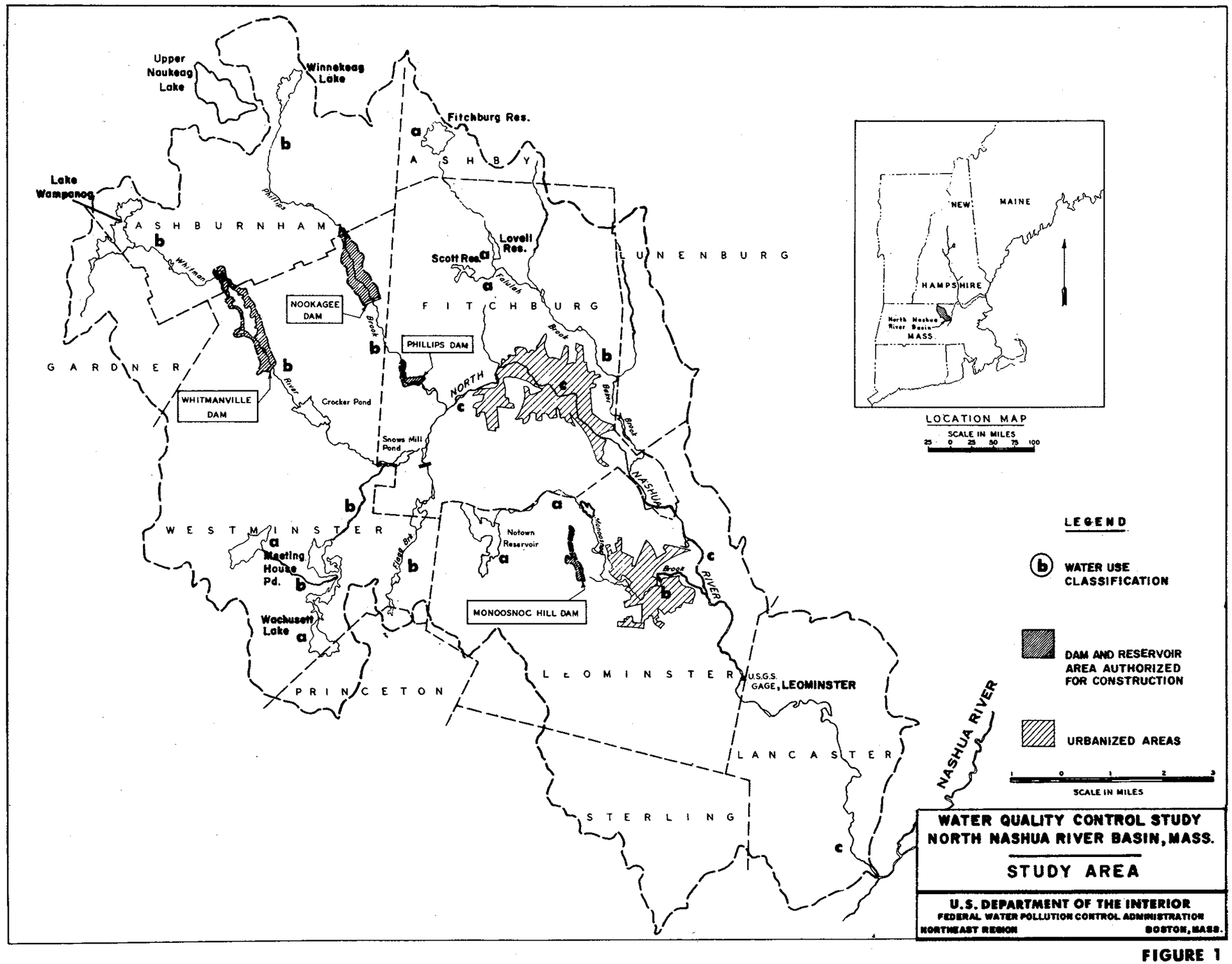

Upper Naukeag Lake
Winnekeag Lake
Fitchburg Res.
Lake Wampanoag
ASHBURNHAM
Whitman
Phillips
Scott Res.
Lovell Res.
LUNENBURG
FITCHBURG
Falulah
NOOKAGEE DAM
Brook
PHILLIPS DAM
GARDNER
WHITMANVILLE DAM
River
Crocker Pond
NORTH
Burnt
Snows Mill Pond
NASHUA
WESTMINSTER
Meeting House Pd.
Flagg Brk.
Notown Reservoir
Honoosnoc
Brook
RIVER
Wachusett Lake
MONOOSNOC HILL DAM
PRINCETON
LEOMINSTER
U.S.G.S. GAGE, LEOMINSTER
LANCASTER
NASHUA RIVER
STERLING
NEW
MAINE
HAMPSHIRE
North Nashua River Basin
MASS.
LOCATION MAP
SCALE IN MILES
25 0 25 50 75 100
LEGEND
(b) WATER USE CLASSIFICATION
DAM AND RESERVOIR AREA AUTHORIZED FOR CONSTRUCTION
URBANIZED AREAS
1 0 1 2 3
SCALE IN MILES
WATER QUALITY CONTROL STUDY
NORTH NASHUA RIVER BASIN, MASS.
STUDY AREA
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
NORTHEAST REGION
BOSTON, MASS.

FIGURE 1

present. The major contributions are expected to be from the industrial pollution sources and to a lesser degree from cities and towns along the North Nashua River. The implementation program to achieve the water quality standards will result in a marked reduction of pollutants discharged in the stream. But even though a high degree of future treatment is achieved, it can be expected that treated residual waste loadings to the river, though much less than at present, will increase with time due to industrial and population growth.

29. Augmentation Requirements. - The minimum flow requirements for water quality control in the North Nashua River were presented to the Corps in the 1968 report of WQO. The report established requirements at the Leominster Gage and were subsequently updated based upon more critical measurements at Arden Mill Dam upstream from the Leominster Gage (Plate 2-1). With the targets set by WQO, the New England Division determined the storage and releases necessary to meet these requirements. The study revealed that storage of 3,800 acre-feet would provide with 95% dependability the flows needed for water quality control. The storage requirements includes 100 acre-feet to compensate for evaporation and other losses. A detailed analysis of the water quality storage requirements were included in the Hydrology Memorandum No. 1 (Revised). The manner of operating the water quality releases and the relationship of the releases with the gaging stations and the industrial water users were presented in Paragraph 5, Page 8 of the "Justification" report included as Appendix A to the Whitmanville GDM.

30. Thermal Simulation Analysis. - Studies were made in an attempt to predetermine the effect of Nookagee Lake Project on the quality of stored and released waters. Analyses consisted of a determination of the daily temperature stratification in the lake during simulated operation of the project for three historical study years: 1956 (average runoff year); 1964 (drought year); and 1969 (wet year). Density current analyses were also performed using data resulting from the thermal stratification analyses. The release temperature objective used in these studies was the natural average stream temperature variation for Phillips Brook. These analyses, which were used to determine the number and spacing of water quality control outlets, are reported in detail in Appendix E of this design memorandum.

31. Reaffirmation of Need and Value. - By letter dated 29 September 1971, the Office of the Chief of Engineers requested that the Environmental Protection Agency reaffirm its previous recommendation that flow augmentation be included in the North Nashua River Projects. The Environmental Protection Agency had defined the need and had determined that the "attendant benefits were widespread" in its 1968 report and again in its letter of 3 August 1971 (Exhibit C-3). EPA's interim reply to OCE's latest request indicates that the need remains for flow augmentation. The current evaluation being made by the Agency is based upon a modified policy that is still in a development stage (Exhibit C-4). The tentative values of minimum stream flows cited in the letter dated 13 October 1972 pertain to the Leominster Gage reach of the North Nashua River and not the more critical reach at Arden Mill. Base flow requirements at the Leominster Gage appear to be reduced for the months of July and August but increased for May, June, September, and October. When the agency completes its study, their recommendations will be reviewed and adjustments will be made in the water quality control storage as needed. Any adjustment in the storage required will be made at the Nookagee site and not at Whitmanville Lake. The Whitmanville site is capable of providing flow augmentation only when the recreation pool is released after Labor Day and has a maximum capability of 1,400 a.f.

32. Support for Water Quality Control. - The most ardent support for the cleanup of the North Nashua and Nashua Rivers has emanated from the Nashua River Watershed Association (NRWA). With dedication and determination, this group (total membership 1970 - 357) has successfully obtained the cooperation and active support of conservationists, local and state agencies and industry towards obtaining their goal of turning the basin from an open sewer to a viable public waterway and attractive recreational area. The three prong objectives of this group include: terminating pollution, protecting the river and adjacent land from excessive development (establish a greenbelt), and enhancing recreation and conservation aspects.

In addition to the Environmental Protection Agency and the Nashua River Watershed Association, expression of support for improved water quality has been made by:

Senator Edward M. Kennedy

Congressman Robert F. Drinan

Commonwealth of Massachusetts
Water Pollution Control Division

New England River Basins Commission

Cities of Fitchburg and Leominster

Nashua River Reservoir Company

Montachusett Regional Planning Commission

33. Nashua River Model River Basin Demonstration Project. - The New England Regional Commission, established by the 1965 Public Works and Economic Development Act, has sponsored a Nashua River Model Basin Project. The project has the objective of demonstrating to the rest of the nation that with proper planning, coordination and reasonable financial backing, an open sewer (North Nashua and Nashua Rivers) can be converted to a viable public waterway. The project is being planned by the Program Management Group which is chaired and staffed by the New England River Basins Commission and includes representatives from the Massachusetts Division of Water Pollution Control, the New Hampshire Water Supply and Pollution Control Commission, the New England Interstate Pollution Control Commission and EPA. The New England Regional Commission allocated $1.25 million of its FY 1971 budget and $1.042 million of its FY 1972 budget to support this project. An additional $0.865 million of the FY 1973 budget is expected to go to the project. The Program Management Group has indicated that even in their early stages of planning, they are aware of the need of flow augmentation for water quality from Nookagee and Whitmanville in order to reach their objective.

34. Progress in Abating Pollution. - Highlights of progress made by communities on the North Nashua River in combating pollution include:

a. Fitchburg. - Weyerhaeuser, Fitchburg, and Fitchburg Paper signed contracts describing their financial agreement with

each other to build the West Fitchburg treatment plant. This agreement was approved by State and Federal water pollution control agencies. Final plans for the plant were completed and construction bids are being solicited. The plant will treat its waste with activated carbon, producing a high quality effluent. Final plans for the East Fitchburg plant have been completed and submitted to the Division of Water Pollution Control for approval and funding. The City of Fitchburg and its participating industries expect to break ground late this fall and to have both plants in operation in 1974.

b. Leominster. - Construction has been completed on the rehabilitation of Leominster's old sewage treatment facility. This plant is now operational and handles domestic waste plus pretreated waste from Borden Chemical and Foster Grant Companies.

c. Westminster. - On 3 December 1971, the Town of Westminster was placed on an abatement timetable by the Massachusetts Water Resources Commission. A preliminary engineering report is due by December 1972, final plans are to be submitted by April 1973, construction is to be started by January 1974 and to be completed by January 1975.

d. Remaining Communities. - Impressive gains have also been made by communities along the Nashua River including Lancaster, Clinton, Groton, Pepperell, Ayer and Nashua.

K. GEOLOGY

35. General. - The dam site is located on Phillips Brook, which flows through the central upland of Massachusetts, a region of low to moderate relief underlain by crystalline rocks. Although considerably modified by glaciation, the topography is fairly subdued and regular. Long, broadcrested ridges rise in fairly smooth but generally steep slopes above wide valleys which are constricted locally by extensive glacial outwash and till. The till forms a generally thin blanket on the hills and ridges and thick deposits in the valleys. Overlying the till in the valleys are outwash features consisting of rough, irregular, knobby terraces along the valley sides and flat plains in the valley bottoms. The bedrock of the region consists of a series of closely folded Carboniferous rocks, mainly schist and gneiss with large areas of granite and pegmatite. The folds trend generally north-south.

36. Foundation Exploration. - Investigations of survey report scope were initiated at the site in April 1963. Four borings were completed and the results of the investigations were presented in the "Water Resource Development Plan, North Nashua River Basin, Merrimack River, Massachusetts, Appendix E." Detailed investigations for preparation of final designs were begun at the site in December 1970. Fifty-seven foundation test borings, including one boring to obtain undisturbed samples for tests, have been completed to date under the current program. The location of all the completed borings is shown on Plan of Foundation Explorations, Plate 2-9.

37. Site Geology. - At the site, Phillips Brook flows in a shallow channel which follows a rather winding course through the outwash deposits in the valley bottom. The outwash, ranging in thickness from 5 feet up to 20 feet, consists generally of silty, sandy gravel and gravelly sand, and extends up both abutments thinning out against the underlying till surface on the higher slopes. In the valley bottom the outwash is underlain by thick lake beds consisting of stratified sands and silt which extend to depths of more than 60 feet. Apparently randomly oriented sheets or lenses of till occur in the lake beds. Till occurs below the stratified lake sediments in the valley bottom and lower parts of the abutments and extends to the bedrock surface. The till is variable but consists generally of gravelly, silty sands and silty gravels with numerous cobbles and boulders.

Bedrock is exposed in extensive areas high on the left abutment and in bold cliffs both immediately downstream from the dam and extending high above the dam on the left abutment slope. Rock occurs at depths of less than 10 feet on the left abutment and slopes steeply from the left abutment toward the valley bottom where it is buried to depths of more than 90 feet under Route 12. On the right abutment, the bedrock is at depths of more than 40 feet. Relations between the various overburden materials and the bedrock are shown on Plates 2-10 and 2-11, Dam, Geologic Sections, and Spillway, Geologic Section.

38. Bedrock Characteristics. - The spillway and large portions of the discharge channel are located in the bedrock on the left abutment. The bedrock consists mainly of dark gray, fine to coarse-grained granitic schiest. Although the rock is generally fresh, weathering has occurred along fairly closely-spaced foliation planes and joints in the upper 10 feet of rock below the rock surface. Foliation dips generally at low angles except where it is obscure or contorted in granitized zones. Horizontal jointing is common throughout but joints at 30°, 45°, and 60° also occur at most localities. Seepage through the embankment foundation will be controlled by an impervious upstream blanket and grouting will only be done at the spillway weir and where bedrock is shallow on the left abutment.

L. OTHER SOLUTIONS CONSIDERED

39. Flood Problem. - Alleviation of the flood problem could be accomplished by either construction of flood control reservoirs alone; restrictive zoning measures with evacuation of the flood plain; levees and improved channels for the protection of local damage centers; channel diversion and relocations; or a combination of reservoirs, local protection and restrictive flood plain zoning. The alternative of constructing flood control reservoirs alone or the plan to implement restrictive zoning measures in combinations with evacuation of the flood plain were considered as conceptual alternatives and were discarded since they were deemed impractical. Alternatives such as major channel improvements and channel diversion were found to be practical and were subjected to careful examination and were compared to the authorized project. The authorized project, in essence, consists of a combination of reservoirs, local protection projects, and restrictive zoning.

a. Conceptual Alternatives -

(1) Reservoirs Alone - Utilization of reservoirs alone to provide flood protection for communities along the North Nashua as well as the Nashua Rivers was determined to be impractical due to prohibitive cost and the limited sites available for such reservoirs. It was further deemed unnecessary to protect both basins end to end since the lower end of the North Nashua Basin and the Nashua River Basin in general are relatively undeveloped and ideally suited to protection by restrictive zoning. Flood protection was found to be warranted in the highly developed areas of the cities of Fitchburg and Leominster, which are located in the upper end of the North Nashua River Basin.

(2) Evacuation of the Flood Plain - The alternative of restrictive zoning and evacuation of the flood plains was considered impractical in the primary flood-prone areas of Fitchburg and Leominster. The developed flood plains in Fitchburg and Leominster are extensive and comprises the "core" of both cities as evident by Plates 2-14, 15, and 16. The impact on the communities of evacuation of such extensive areas would be catastrophic.

b. Practical Alternatives - Detailed studies were made in 1963 of the three alternatives which were considered the most practical. The projects studied included: major channel improvements,

closed conduit diversion, and a tunnel diversion.

(1) Major Channel Improvements - Existing buildings, bridges, and other structures along the upper North Nashua River present serious limitations on construction of local protection type improvements against flooding of the magnitude of the standard project flood. As an alternative plan of protection, a major channel improvement project was considered which would extend for a distance of approximately eight miles from upstream of Snows Mill Pond in the vicinity of Mill No. 8 of the Weyerhaeuser Company, downstream to the Fitchburg Airport. It would necessitate the taking of various buildings as well as the replacement of 23 of the 36 bridges existing within the limits of the protection plan. Project costs would amount to $30,700,000 at 1972 price levels. Apart from the razing of bridges and buildings and overall disruption to the city, this project plan would provide no opportunity for development of other related water resources and would provide no protection to the city of Leominster, the Baker Brook Area, or other downstream communities.

(2) Closed Conduit. - As an alternate solution, consideration was given to inclosing the North Nashua River channel in a dual conduit for a distance of about three miles through critical damage zones, with channel excavation and widening wherever possible. This plan offered the valuable opportunity of utilizing the top of the dual conduit for a roadway or other land use. The cost of this plan was found to be inordinately expensive, estimated at $57,600,000 (1972 price levels) and offered no opportunity for development of other related water resources, or protection for Leominster, the Baker Brook Area, or other downstream communities.

(3) Channel Diversion. - Another alternate plan of protection provided for channel diversion in the form of by-pass tunnel drilled through rock and extending for a distance of 7,000 feet through the heavily built-up downtown section of the City of Fitchburg. At other damage zones, flood walls and channel improvement would be utilized as a means of protection. Costs for the plan of improvement were estimated at $38,400,000. Although not as disruptive as the alternates considered in Paragraph (1) and (2), the plan would be inordinately expensive and would similarly

offer no opportunity for development of other water resources or provide protection for Leominster, the Baker Brook Area, and other downstream communities.

c. Authorized Project - The water resources development plan authorized for the North Nashua River incorporates the combination of reservoirs, channel improvements and zoning to accomplish its objective. With a minimum number of reservoirs (4) and three channel improvement projects the industrial heartland of both cities would obtain a high degree of protection.

For the non-developed and rural areas, the plan recommended that encroachment lines downstream of the dams be established. This Division has actively urged that flood plain zoning be established not only for communities along the North Nashua but particularly for communities on the Nashua River where the prime undeveloped flood plain exists. The four dams and three local protection projects, comprising the present plan for the North Nashua River Basin, of which Nookagee Lake is one element, would cost, according to a 1972 estimate, $30,900,000 and would provide recreation and water quality control benefits in addition to flood control. The alternatives to the flood problem have been reevaluated during preconstruction planning. The reevaluations included an environmental assessment as well as an economic assessment. The authorized plan for the water resource development of the basin was confirmed to be the most beneficial, economical and the least disruptive environmentally.

40. Water Quality Problem. - The Federal Water Pollution Control Administration in its 1968 study considered possible alternatives to low flow augmentation. It included: (a) reaeration of the stream and or effluents and (b) tertiary waste treatment. Other alternates such as waste disposal underground and waste holding in lagoons for discharge during favorable flow conditions were considered impractical because of the large volumes of plant discharge and the inordinate size of facilities that would be required. The Weyerhaeuser operation alone has a discharge rate of over 12 mgd. In addition, flows in the river must be maintained to provide process water for downstream locations also makes it impractical to collect all wastes for long distance transmission to treatment and discharge to a larger watercourse.

The study concluded that the alternates could not provide benefits equivalent to low flow augmentation. Low flow augmentation in addition to maintaining desired BOD and dissolved oxygen levels provides dilution for non-degradable pollutants, better stream velocities to inhibit obnoxious aquatic growth, higher water levels for improved aesthetic and recreation enjoyment, a stabilizing influence for all downstream reaches regardless of loading conditions which may not follow a predictable pattern, and a smaller likelihood of being rendered obsolete by changing needs and technology.

M. DESCRIPTION OF PROPOSED STRUCTURES AND IMPROVEMENTS

41. General. - A description of each of the principal elements of the proposed plan for the Nookagee Lake project is presented in the following paragraphs. Studies to develop design details for each element are underway and will be presented in subsequent Design Memoranda.

42. Dam Embankment. - The project plan provides for the construction of a zoned rolled earth fill dam with upstream and downstream rock slope protection. A profile of the dam and tentative embankment sections are shown on Plate Nos. 2-4 and 2-5. Major factors influencing embankment design are the foundation conditions and the availability and characteristics of embankment materials. Suitable material from the required excavations will be utilized in the rock protection layers and the random fill zones of the embankment. The impervious fill zone will be constructed of material obtained from borrow excavations in a glacial till deposit on the right side of the valley downstream of the dam site. The outside embankment slopes have been established tentatively on the basis of embankment stability studies including shear tests. Seepage through the embankment foundation will be controlled by an impervious upstream blanket. Details of the embankment design will be presented in Design Memorandum No. 8, Embankments and Foundations.

43. Spillway. - The spillway will be an "L" Shape side channel type located in the left abutment. For details, see Plate Nos. 2-3

and 2-8. The weir will be a concrete ogee section founded on rock at the high point of the channel. The length of the weir will be 215 feet at spillway crest elevation 835.0 feet, m.s.l. The height of the concrete weir above the spillway approach channel will be 5 feet, making the maximum elevation of the approach channel 830.0 feet at the upstream face of the spillway weir. The excavated approach channel will slope down into the reservoir for drainage. The spillway discharge channel, excavated in earth and rock, will be of the parallel type and will be about 1,360 feet long. It will slope from invert elevation 823.5 at the weir at a 9% grade for 150 feet then at a 2% slope for a distance of 100 feet and continuing at a 10% slope from this point for 680 feet at which point it will be sloped to drain from elevation 740.0 feet m.s.l. for a distance of about 430 feet, where it will enter Phillips Brook.

44. Outlet Works. - The outlet works will be located near the right abutment, under the dam, and will consist of an inlet channel, an intake tower, a conduit on earth under the dam, an outlet structure, and an outlet channel. Details of the outlet works are shown on Plate Nos. 2-5, 2-6, and 2-7.

a. Inlet Channel - A 600-foot long inlet channel with a uniform width will be excavated, with bottom elevation of 753.0 feet, m.s.l.

b. Intake Tower and Operating House - The intake tower will house the flood control and water quality control outlet works. It will be a dry well type structure about 120 feet in height and will be located about 220 feet upstream from the centerline of the dam. A service bridge will provide access from the top of dam. Plan and profile views of the intake tower are shown on Plate Nos. 2-3 and 2-5.

The intake structure at the base of the tower will have an invert elevation of 753.0 feet m.s.l. and will consist of a 10-foot high by 8-foot wide trash bar structure, a rectangular entrance conduit 3 feet wide by 4 feet high with a vertical slide service gate and an emergency slide gate of the same dimensions. A vent pipe will be installed within the tower to satisfy the air demand at the service gate when operating at partial openings. Provisions will be included on the upstream face of the tower to permit lowering a

steel bulkhead for repair of the conduit or emergency slide gate.

The water quality control outlet works will consist of three 2'-6" x 3' inlets, controlled by 30-inch knife gates, discharging into a 48-inch diameter standpipe. Externally mounted slide gates will be provided at each intake for emergency closure. The vertical standpipe will discharge into a branch conduit at a point upstream from a 3' x 4' slide gate. The branch conduit, in turn, will discharge into the flood control conduit. A vent pipe will be provided for this gate. The centerline elevations of water quality control inlets will be 805, 793, and 781 feet m. s. l.

The intake tower will contain three floors: (1) the heater room floor (elevation 834.5), (2) operating floor (elevation 847.0), and (3) the equipment room floor (elevation 862.0). The tower will house the high pressure oil hydraulic system for operation of the gates, a continuous waterstage recorder, an electrical switchboard, an emergency diesel engine generator, a high-lift crane, a forced warm air heating system, oil pump, motor standby unit, and an elevator. The gate chamber at elevation 761.5 will contain two individual hydraulically operated service slide gates and one emergency slide gate, and a sump pump located in a well. An elevator will be provided for travel from the operating floor to elevation 761.5. Electric power will normally be obtained from commercial sources.

An elevator is being provided because of the height of tower and the need for frequent inspection, servicing, and operation of the gates, valve, and pumps. Provisions will be made for elevator stops at the water quality control inlets.

c. Conduit and Transition. - The 3' x 4' conduit from the 48-inch diameter water quality standpipe, will join the straight through 3' x 4' flood control conduit at a point approximately 30 feet downstream from the service gate. At this point the height of the conduit will be uniformly increased to 5 feet in a length of 13 feet. The water quality conduit will converge with the straight conduit at the rate of 1-foot in 3 feet. The reinforced concrete conduit will be founded on earth under the dam and will have a total length of approximately 420 feet. It will slope at about 1.19-percent from the end of the transition to the outlet at elevation 748.0 feet, m. s. l.

d. Outlet Channel. - The outlet channel, excavated in earth will be 12 feet wide and runs 720 feet to its terminus at Phillips Brook. The initial 60-foot segment of the channel contains a concrete stilling basin with an invert transition from elevation 748.0 to 744.0 feet, m.s.l.

45. Reservoir Clearing and Stripping. - Releases for water quality control will expose a considerable amount of impoundment bottom. This exposure of pool bottoms is considered an undesirable environmental effect since it would be more desirable if the pools could be maintained at a stable level. For an average year, approximately 90 acres will be exposed and for 1 in 10 dry years, the exposure is expected to be as much as 140 acres out of a total water surface area of 190 acres. Understandably the thought that the project will introduce extensive mud flats into the basin is of concern to conservationists and the State. The Governor, in his letter dated 23 July 1971 (Exhibit C-6) expressed his concern and recommended that adequate measures be taken to alleviate the condition. The U. S. Fish and Wildlife Service report contained the recommendation that the area between elevations 802 and 816 be stripped of all organic material down to mineral soil. The Service's recommendation was based upon the desire to eliminate mud flats, to provide more desirable spawning areas for fish and to provide an aesthetically pleasing area. However, the report by the Service recommended that approximately 45 acres of shallow impoundment bottom be left undisturbed so as to provide "fair" to "good" quality habitat for waterfowl nesting, nature study, and bird-watching.

In light of the above reasons, the present design includes grubbing and stripping the reservoir from the stream bed to elevation 817 (1-foot above the permanent pool). Clearing of the reservoir will extend to elevation 818 (2 feet above the permanent pool). Approximately 45 acres in the upper end of the reservoir will be left undisturbed as recommended. The Service has been requested to furnish a more clearly defined area where wildlife habitat should remain. Stripping of the reservoir is primarily for environmental reasons and encompasses approximately 150 acres at an added cost of approximately $0.5 million.

46. Access. - Access to the top of dam will be by an extension of the top of dam roadway to the spur road running between Bean

Porridge Hill Road and the truncated end of Ashburnham Street.

47. Administrative Facilities and Utilities. - A combined utility building and garage, 32 feet by 75 feet, will be constructed downstream of the dam along the spur road, see Plate No. 2-3. The building will include office, toilets, heater room, workshop and garage facilities. Telephone and electric service to the administrative facilities and dam will be from Ashburnham Street to the spur road then along the top of dam.

48. Housing Facilities.

a. Minimum Facilities - The minimum housing facilities considered necessary for this installation consist of living quarters for the operator such that he can regulate the gates during flood emergencies on a timely basis and also to minimize vandalism of Government property. The cost of the operator's residence, including engineering, design, supervision, administration, and utilities within the lot line is estimated to be $29,000.

b. Rental Housing Survey. - In accordance with ER 415-2-301, dated 1 February 1972, "Construction Policies and Practices", a survey and study was conducted covering an area of about 3-1/2 miles in radius of the damsite for the Nookagee Lake Project. The study has revealed that there is an acute shortage of rental and apartment units in the Westminster-Ashburnham area and a great number of units are needed to satisfy the space requirements for a broad socio-economic range. There is a particular lack of rental units that would be in keeping with those units normally supplied for an operator's quarters, therefore, it is recommended that provisions be made for the construction of a new dwelling. The existing dwellings to be acquired within the project are of the older inferior type and others which do not lend themselves to feasible renovation or relocation.

49. Overlook Area. - It is proposed to construct a visitor's overlook area high on the left abutment. A roadway, parking area, and picnic tables are planned. Access will be from the Relocated Route 12.

N. INSTRUMENTATION OF DAM

50. Instrumentation. - No instrumentation is planned for the dam embankment. Data from the consolidation test and experience with similar embankment materials indicate that construction pore pressures will be insignificant. The character of the embankment materials is such that significant horizontal or vertical movements are not anticipated. Instrumentation for observation and recording of seismic events will be considered at a later date.

O. PROJECT REFORMULATION AND EVALUATION

51. Project Reformulation. - During the review of the 1965 Survey Report of the North Nashua River Basin, the Department of Health, Education, and Welfare, pointed out the need for providing in these projects storage for water quality to supplement the waste treatment program. HEW stated that their studies "indicated that presently available treatment methods cannot alone control the polluted condition of the stream" (North Nashua River) and "even partial provisions for stream flow regulation would result in substantial quality improvement with attendant benefits within the study area." In response, the Chief of Engineers assured HEW that "prior to initiation of construction, studies will be made concerning the need for storage for water quality control".

In September 1969, the local interests, through the Mayor of the City of Fitchburg, Massachusetts, withdrew their support for the water supply aspects of both the Nookagee and Whitmanville Lake projects. As a result of the withdrawal of support for the water supply aspects and the requirement to determine the need for storage for water quality control, this office initiated a restudy of the purposes for both the Nookagee and Whitmanville projects.

Since the issuance of the 1965 Survey Report of the North Nashua River Basin, the Water Quality Office of the Environmental Protection Agency has set up minimum flow requirements for water quality control in the North Nashua River. With the targets set by the WQO, letter dated 31 October 1969, the New England Division determined the storage and releases necessary to meet these requirements. The study revealed that impoundment of 3,800 acre-feet would provide the water needed for flow augmentation for water quality with 95% dependability.

In the reformulation of the projects it was noted that the Whitmanville site offered little flexibility due to restrictions. One restriction, the regional high school, was built at an elevation which would not permit, economically, raising the dam. Accordingly, Nookagee had to provide the bulk of the storage for water quality control. Six plans were derived, studied and assessed. During the period of assessment, it became evident that the magnitude of drawdowns at the Nookagee site would limit the extent of recreational development at that site. Releases from the reservoir for water quality control would come at the time when the recreational demands would be the greatest and based upon past experience, drawdowns greater than 5 feet are considered excessive and detrimental to recreation by exposing large unsightly areas along the shoreline. Studies revealed that the drawdowns at Nookagee could be as much as 15 feet. The drawdown analysis terminated with the conclusion that the most favorable site for major recreation development would be at Whitmanville, Stability of the recreation pool at Whitmanville would be subject to demands for water quality releases as well as releases for industrial water equivalent in amount to storage in the existing privately-owned Westminster Reservoir. However, to stabilize the recreation pool at Whitmanville, it was concluded that all water quality releases during the recreation season would be made from Nookagee. After Labor Day the releases from Nookagee would be stopped and the water quality demands would be met by Whitmanville. Fluctuation of the recreation pool stemming from the demands of the industrial water users would be eliminated by the operation of a two pool system.

Two pools would be created by utilizing the existing Westminster Dam presently located 3/4-miles upstream of the new Whitmanville Dam. It is envisioned that the pool behind the existing dam would become the recreation pool and the storage between the new and existing dams would be used basically to meet the demands of the industrial water users. Present plans envision operating the two pool system by:

a. Satisfying the initial demands for industrial water by a drawdown of 1.5 feet from both pools (i.e., drawdown from El. 826.6 to El. 825.1).

b. Meet supplementary demands for industrial water with the storage between the two dams.

The analysis concluded that the most efficient and least disruptive (environmentally) means to implement development of the water resource plan, as previously authorized by Congress, was by construction of a multi-purpose dam and lake at Whitmanville and a dual-purpose project at Nookagee.

The following summarizes the revised plan:

Whitmanville Lake. - Total storage capacity of 7,850 acre-feet, equivalent to 8.4-inches of runoff. The total storage has allocations of: 1,150 acre-feet (1.2-inches) to replace existing water supply at Westminster Reservoir which will be inundated by the dam; 5,300 acre-feet (5.7-inches) for flood control; and 1,400 acre-feet (1.5-inches) seasonal joint-use for flood control, recreation, and water quality. Operationally the full flood control storage of 6,700 acre-feet will be available from November through March. Toward the end of the spring runoff in April, a recreation pool would be established by retaining 1,400 acre-feet within the flood control zone. This seasonal pool would be retained until the close of the recreation season in September. At that time the pool would be lowered to provide full flood control storage. Releases from the seasonal pool would be utilized to meet the water quality demands for September and October.

Nookagee Lake. - Total storage capacity of 8,400 acre-feet equivalent to 14.6-inches of runoff. The total storage includes allocations of: 700 acre-feet (1.2-inches) for conservation storage and also to serve as a minimum winter pool; 3,000 acre-feet (5.2-inches) for water quality control; and 4,700 acre-feet (8.2-inches) for year round flood control.

A schematic diagram of the reservoir system is shown by Figure 2.

As a result of the reformulation, the Division Engineer recommended that the assurances to be furnished by the non-Federal interests be modified for the Whitmanville and Nookagee projects such that responsible non-Federal interests are required to give assurances satisfactory to the Secretary of the Army that they will:

a. In accordance with the Federal Water Project Recreation Act of 1965:

(1) Administer project land and water areas for recreation and fish and wildlife enhancement;

(2) Pay, contribute in kind, or repay (which may be through user fees) with interest, one-half of the separable first costs of the reservoir projects allocated to recreation and fish and wildlife enhancement, the amount involved being currently estimated as follows:

Reservoir	Amount
Whitmanville	$175,000

(3) Bear all costs of operation, maintenance, and replacement of recreation and fish and wildlife lands and facilities, the amounts involved being currently estimated on an average annual basis as follows:

Reservoir	Amount
Whitmanville	$ 18,000

Provided that the sizing and responsibility for development, operation, maintenance, and replacement of the recreation and fish and wildlife enhancement features of the reservoirs may be modified in accordance with the alternative provided in the proposed Federal Water Project Recreation Act cited above, depending upon the intentions of local interests regarding participation in the costs of these features at the time of reservoir construction and subsequent thereto, and that appropriate adjustments reflecting such modifications may be made in the allocation of costs to other project purposes;

b. Protect channels downstream of the reservoirs from encroachments which would adversely affect operation of the system;

c. Hold and save the United States free from all damages due to water-rights claims resulting from construction and operation of the reservoirs;

d. Exercise to the full extent of their legal capability, control, against removal of water in the basin which will affect the reservoirs' water quality storage and the development of dependable stream regulations; and

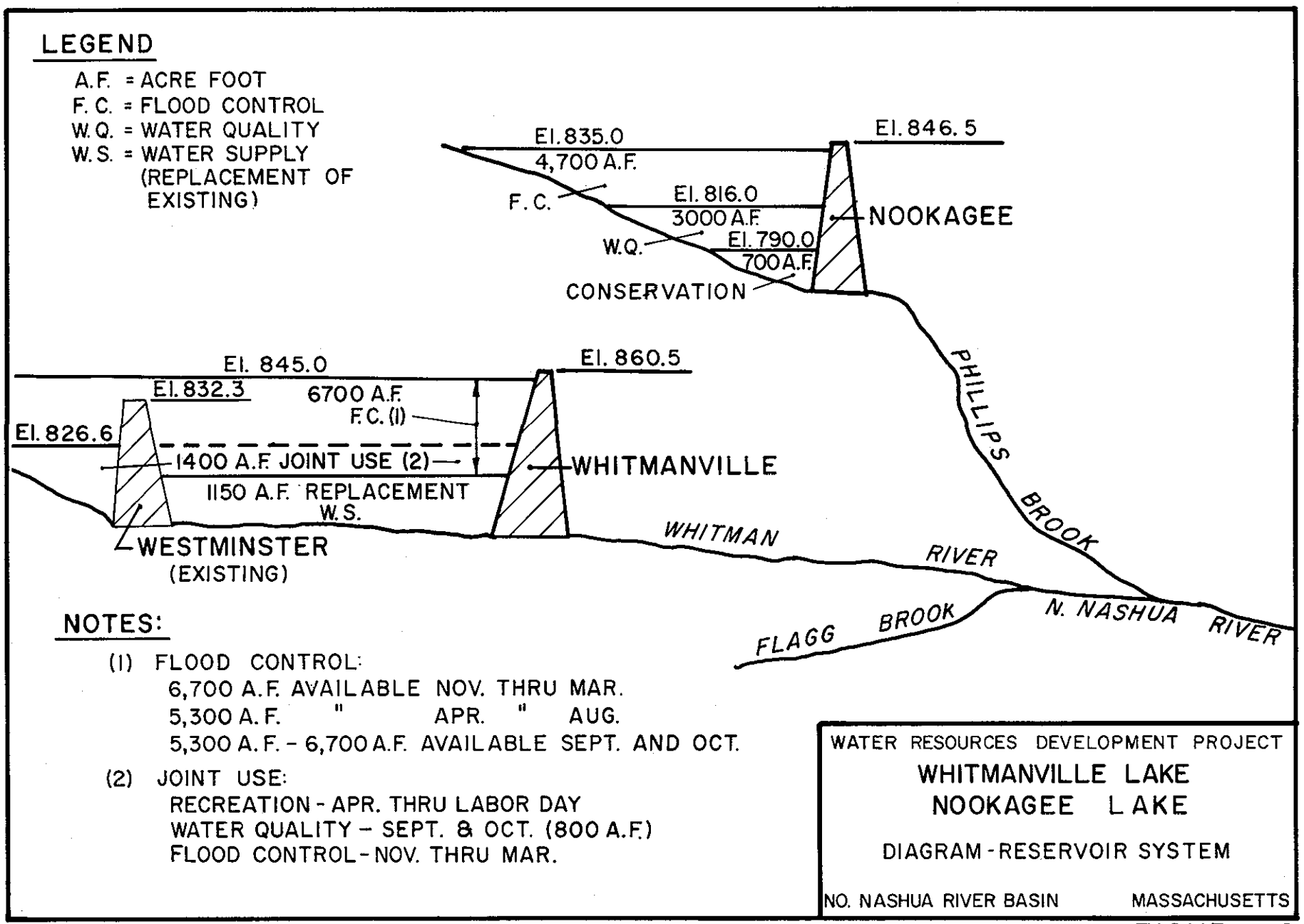

LEGEND
A.F. = ACRE FOOT
F.C. = FLOOD CONTROL
W.Q. = WATER QUALITY
W.S. = WATER SUPPLY (REPLACEMENT OF EXISTING)
El. 835.0
4,700 A.F.
F.C.
El. 816.0
3000 A.F.
W.Q.
El. 790.0
700 A.F.
CONSERVATION
El. 846.5
NOOKAGEE
El. 845.0
El. 832.3
El. 826.6
6700 A.F.
F.C. (1)
1400 A.F. JOINT USE (2)
1150 A.F. REPLACEMENT W.S.
El. 860.5
WHITMANVILLE
WESTMINSTER
(EXISTING)
PHILLIPS BROOK
WHITMAN RIVER
FLAGG BROOK
N. NASHUA RIVER
NOTES:
(1) FLOOD CONTROL:
6,700 A.F. AVAILABLE NOV. THRU MAR.
5,300 A.F. " APR. " AUG.
5,300 A.F. - 6,700 A.F. AVAILABLE SEPT. AND OCT.
(2) JOINT USE:
RECREATION - APR. THRU LABOR DAY
WATER QUALITY - SEPT. & OCT. (800 A.F.)
FLOOD CONTROL - NOV. THRU MAR.
WATER RESOURCES DEVELOPMENT PROJECT
WHITMANVILLE LAKE
NOOKAGEE LAKE
DIAGRAM - RESERVOIR SYSTEM
NO. NASHUA RIVER BASIN MASSACHUSETTS

FIGURE 2

e. Exercise, to the full extent of their legal capability, control against removal of stream flow made available by reservoir storage for water quality.

The proposed changes in the projects were submitted on 12 February 1971 to the Office of the Chief of Engineers for review and approval as a report entitled, "Whitmanville Dam and Lake, Whitman River - Nookagee Dam and Lake, Phillips Brook, North Nashua River Basin, Justification for Altering Project Purposes." The report was approved as a basis for further planning by the Office of the Chief of Engineers on 28 May 1971. (See Appendix A of the Whitmanville GDM for contents of the report and letter of approval). Comments by OCE have been incorporated in this design memorandum.

The approved alterations thereby make the projects' purposes as:

Whitmanville

Flood Control
Recreation
Industrial water supply (replacement of existing)
Water Quality Control

Nookagee

Flood Control
Water Quality Control
Recreation (limited)

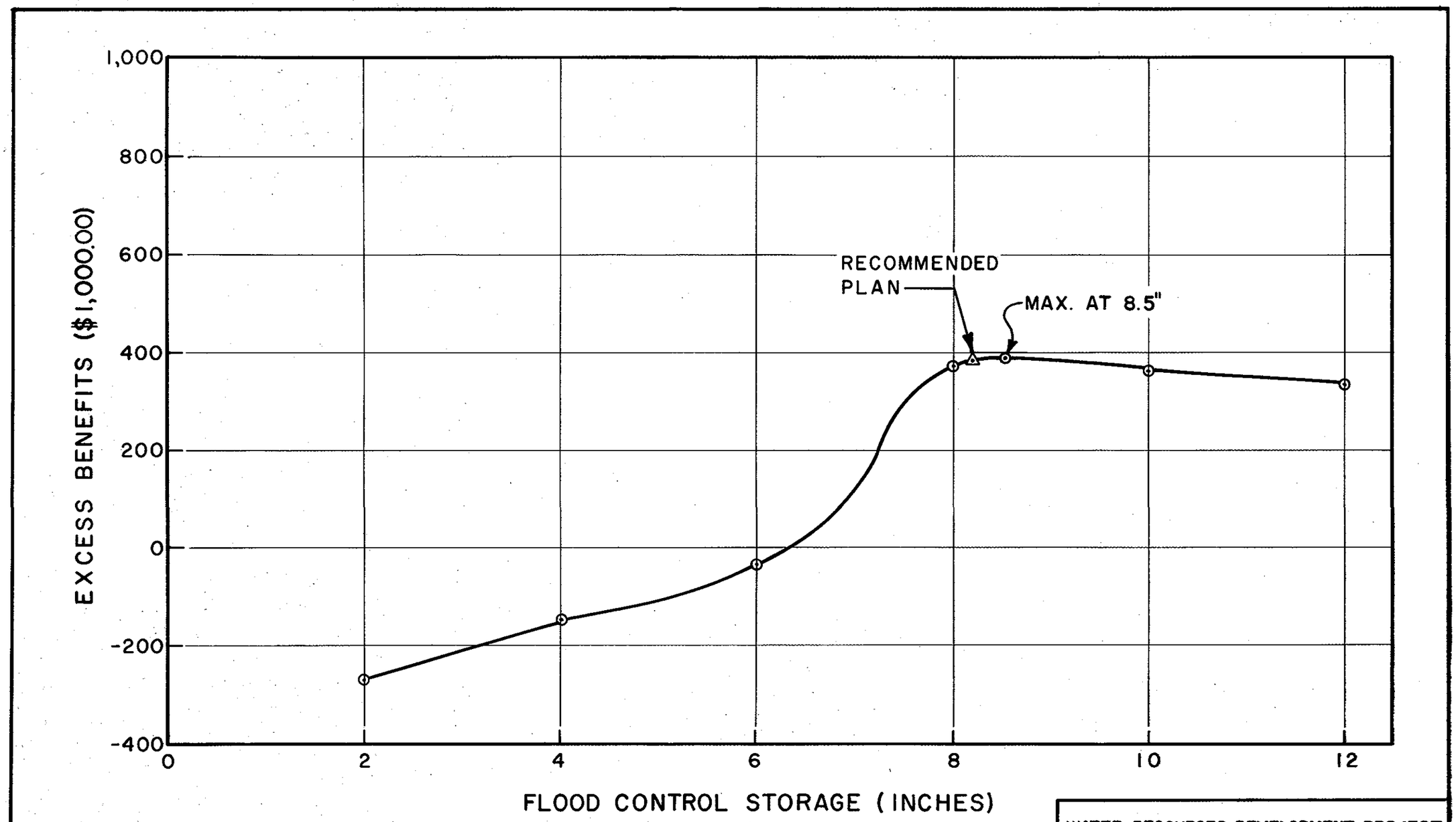
52. Evaluation. -

a. Flood Control. - The primary interest for improvement in the basin is to reduce the destructive flood damages in the urban areas of Fitchburg and Leominster, Massachusetts. A study was made of the effect of varying the amount of flood control storage in the Nookagee Lake reservoir and considered 2, 4, 6, 8, 10, and 12-inches of runoff. Costs, benefits, and excess of benefits were derived for all six plans. The results of the investigation are shown graphically in Figure 3 which shows a curve of excess annual

benefits for various runoff storages. The curve indicates that the point of maximization of net benefits would be achieved with 8.5-inches of flood control storage. Studies show that 8-inches plus of flood control storage is needed to effectively control the floods of record and the standard project flood. This amount was selected in order to provide a high degree of protection in the highly developed and densely populated urban areas of Fitchburg and Leominster. The actual flood protection provided will be 8.2-inches on a year-round basis and for all practical purposes is equivalent to the 8.5-inches of storage maximized.

b. Water Quality Control. - Studies made indicate that downstream water quality could be enhanced by making provisions in the project for low flow releases. The Water Quality Office, formerly the Federal Water Pollution Control Administration, indicated that presently available treatment methods alone cannot control the polluted condition of the stream and even partial provisions for stream flow regulation would result in substantial improvement with attendant benefits within the basin. Using base flows at four contiguous reaches on the North Nashua River in the Fitchburg-Leominster area, the additional fresh water required to maintain the total flow in the river above acceptable dissolved oxygen levels was determined at the Leominster USGS gage and at Arden Mill Dam (See Plate 2-1). At Leominster, the maximum augmentation required for any one year was determined to be 2,400 acre-feet, whereas for Arden Mills the augmentation was found to be more critical with a requirement of 3,800 acre-feet. The storage of 3,800 acre-feet (3,000 at Nookagee and 800 at Whitmanville) will be adequate to meet the water quality control requirements established at Arden Mill Dam with a 95% dependability. For extremely severe drought conditions such as the critical 1964-66 period (considered as 1 in 100 dry years) the storage would be sufficient for all but 1 month of water quality demands.

53. Summary. - Based upon the unwillingness of the Commonwealth of Massachusetts to financially participate in the recreational aspect; and the Water Quality Office's requirements for minimum flows for water quality; the only variable in the Nookagee Lake project was considered to be the flood control storage. The



WATER RESOURCES DEVELOPMENT PROJECT

NOOKAGEE LAKE

EXCESS BENEFIT CURVE

NO. NASHUA RIVER BASIN MASSACHUSETTS

FIGURE 3

variation of 2, 4, 6, 8, 10, and 12-inches of storage was studied and as previously explained, 8.2-inches, or 4,700 acre-feet of flood control storage is desired to provide the necessary degree of protection for the downstream urban communities. The project is therefore, recommended for construction containing a total of 8,400 acre-feet of storage consisting of: 3,000 acre-feet for water quality control, 4,700 acre-feet for flood control and 700 acre-feet for conservation.

P. CORROSION MITIGATION

54. Corrosion Severity. - The sites for the appurtenant structures of the dam are located at a point on the Phillips Brook which is free from industrial or municipal pollutants thereby the quality of the existing water is generally excellent (Class B). Water quality data collected at the site indicated that the water is basically neutral as noted in Table 10 of Design Memorandum No. 1, Hydrology (Revised). Sampling has indicated that during certain months of the year traces of chlorides (road salts) do appear. The bedrock on which the structure will be located or the soil to be placed against the structures show no sign of being highly corrosive. Consequently, normal corrosive resisting materials will be selected for the structures and the normal amount of concrete protection will be afforded the reinforcing steel.

Q. ACCESS ROADS

55. General. - The alignment of the haul road from the borrow area to the damsite will be specified on the contract drawings. A tentative alignment of the haul road, is shown on Plate 2-17. Alternate alignments will be evaluated during final design of the project. Consideration will be given to the use of part of the haul road for access to the lake. Clearing for the road will be kept to a minimum and will be specified. Where the segment of haul road is found suitable as an access road for recreation, the road will be constructed as a permanent road according to contract plans. Where not used as a permanent access, the haul road will be removed, topsoiled and seeded and left as a trail.

R. CONSTRUCTION MATERIALS

56. General. - The embankment section for the rolled earth-fill dam will be of the zoned type with impervious and random fill zones, drainage features and upstream and downstream rock slope protection. An impervious upstream blanket will be provided to assist in control of seepage through the embankment foundation.

57. Impervious Material. - A source of material suitable for use in the impervious sections of the embankment and the impervious upstream blanket is located on the west side of the valley between Bean Porridge Hill Road and Route 12 approximately .75 miles downstream from the dam. The borrow area includes an extensive and thick deposit of glacial till consisting generally of gravelly, silty sand with numerous cobbles and boulders.

58. Random Material. - Materials from required excavation will consist of outwash materials, lake sediments and till which may be modified within wide limits. All these materials will be utilized in the random fill portion of the embankment.

59. Embankment Drainage Materials, Gravel Bedding and Road Gravel. - Extensive deposits of sands and gravels occur in the region within 10 miles of the site and commercial operations are active in several of these deposits. It is currently planned that drainage materials, gravel bedding and road gravel will be furnished by the contractor from offsite sources.

60. Rock Slope Protection and Riprap. - Rock from required excavations will be available for rock slope protection and riprap. The rock consists mainly of granitic schist with scattered zones and stringers of granite. The rock is closely jointed and has well-developed foliation so that at least in the shallow zones of the excavations, blasting will produce some small rock sizes and considerable fines. Fines will also result from breakdown of schistose phases of the rock and from weathered seams and mud-filled joints. It is expected that overall bulking of the rock will be largely offset by losses in blasting and handling. If additional rock is required, it can be obtained by quarrying on the uphill side of the spillway approach channel.

61. Concrete Aggregates. - In view of the small quantity of concrete required, investigations of sources of aggregate materials has been limited to consideration of commercial sources within a 25 mile haul distance of the site. Complete data on concrete aggregate investigations is presented in Design Memorandum No. 6, Concrete Materials.

S. PUBLIC USE

62. Site Description. - The location of the Nookagee Lake project with respect to public use is most fortunate, since it is in a typical New England rural setting characterized by rolling hills, woods, flowing water and sparse population. The area is readily accessible to more than 840,000 Massachusetts residents and 140,000 New Hampshire residents who live within 40 miles of the lake. The heavily populated cities of Fitchburg, Leominster, and Gardner, Massachusetts are close to the project site.

The availability of the project lands and water for public use will be a significant asset to the surrounding area. It is important, therefore, that public use development be carefully planned and executed, not only to provide recreational facilities for public use, but more importantly, to protect and preserve the natural amenities on the site. Besides the scenic assets of the area, other assets include a fishery, woodland for hiking and allied sports, and a population of small game and birds. No assets of historical or archeological importance have yet been found, but research in that respect will continue in cooperation with local individuals and groups.

63. Planning Concept. - Since non-Federal agencies have decided not to participate, recreational development will be limited to that defined in Regulation ER 1120-2-2400, Paragraph 6b (2) which states, with relation to planning:

"(2) The other level (of planning) anticipates the lack of non-Federal participation and formulates a plan with minimum facilities for public health and safety, consisting of guardrails and turnarounds on existing road ends and minimum sanitary facilities, but includes the acquisition of sufficient lands to support full development to preserve the potentials created by the project."

In keeping with the above regulation, recreational development will be limited to use of the old pavements for boat launching after Fred Smith, Bean Porridge Hill and Dean Hill Roads are truncated. Fred Smith Road will be the major access point to the lake since it provides more suitable road grades, more open land and access to the lake at all pool stages. Facilities for the Fred Smith Road access will include minimum sanitary facilities, a turnaround and informal parking on grass and vacated residential drives. Bean Porridge Hill and Dean Hill roads provide less favorable conditions and their useage will not be emphasized. Facilities at the latter sites will consist of limited informal parking and turnarounds.

Public access to the reach of Phillips Brook below the damsite is comtemplated along the lines recommended by the U.S. Fish and Wildlife Service except that the extent of access appears practical for 1-1/2 miles rather than the 2 miles recommended. The 1-1/2 mile segment of Phillips Brook below the damsite will approximately mitigate the loss of the 1-3/4 miles of stream fishing inundated by the project pool. A field reconnaissance of the reach indicates that access is feasible and desirable. Public access will be obtained by easements wherever possible and acquisitions will be made only if an easement cannot be obtained and where it is deemed essential. The extent of access will be approximately 100 feet wide and equivalent to 16 acres.

T. ENVIRONMENTAL QUALITY

64. Architectural and Engineering Treatment. - Aesthetic criteria for the architectural design of structures and facilities required for this project will insure a harmonious relationship with the sparsely settled rural environment. Private residences and small farms constitute the principal existing habitations in the vicinity. There is no anticipation on the part of local authorities that the character of the environment will be urbanized in the near future.

The predominant structure of this project is an earthfill dam approximately 105 feet in height. Principal ancillary structures are: concrete intake tower with connecting steel and concrete service bridge, spillway, and outlet works. Because of the scale

of these latter features in relation to the distance from which observed, the overall design consideration will be to provide simple mass relationships which are commensurate with the functional uses of each. Concrete will have a Class B finish. Other exterior materials, except ferrous metal, will have natural colors. Ferrous metal will be painted.

The operator's quarters will be a cottage comparable in design with the residences in the area. The cottage will be located adjacent to the spur road south of the dam. Nearby will be a utility building for maintenance activities of the project. The building will be a simple wood framed structure with exterior finish similar to the operator's quarters. Tree and shrub planting will be utilized to screen the utilitarian activities from the public view.

Facilities required for recreational use will be minimal. Extended visits to the project by the public will not be encouraged and no permanent provision will be made for toilets or similar accomodations for visitors. The nearby Whitmanville Lake project is planned to encourage extensive public use and will provide suitable facilities for visitors. Public sanitary facilities for the Nookagee site will be of the chemical type, portable and provided on a seasonal basis.

65. Landscape Architectural Treatment. - Since landscape architecture is the science and art of correctly using land and water for human use and enjoyment, and since the purposes of Nookagee Lake are for human use (flood control and water quality) and human enjoyment (recreation and visual amenities), it follows that landscape architecture will be an important element of design effort. The principles of landscape architecture will be applied during project design to insure:

a. Acquisition of land area sufficient for all project needs including those needs related to visual and aesthetic values.

b. Inclusion in final design of complete site plans for the entire project area, showing not only features to be constructed, but also temporary facilities necessary for construction operations.

c. Inclusion of plans for protection and preservation of existing natural assets including vegetation and land forms.

d. Inclusion of plans for use of plant material as needed for landscape planting purposes such as the softening of architectural lines, tying the new work together and to the surrounding landscape, providing visual amenities, screening and for shade. If necessary, a reforestation plan will be developed.

Development features will be designed to blend with existing site characteristics, so that structures, walks, trails, parking area, and other elements are compatible with the natural environment.

66. Environmental Impact. - A detailed study of the impact of the project on the environment was pursued as required and has been documented in the environmental statement, and has been submitted separately from this memorandum. The study evaluated impacts on the terrestrial and acquatic life forms, analyzed any unique or unusual natural sites found in the area of proposed impoundment, thoroughly considered visual and aesthetic impacts and evaluated the influence of the project on the area. To assist in the environmental impacts study, a consulting firm having the necessary capabilities was engaged.

U. REAL ESTATE REQUIREMENTS

67. Description. - In accordance with ER 405-2-150, dated 11 February 1966, as amended, and with clarifying guidelines set out in teletype ENGCW-OC, R131945Z, dated July 1971, Subject: "Real Estate Acquisition", and teletype ENGCW-OC, R131445Z, dated September 1971, same subject, it is proposed to establish a minimum guide taking line 300 feet horizontally from the conservation pool, elevation 816 feet above m. s.l. and/or the "Guide Taking Line", elevation 840 feet above m. s.l. whichever is the greater. It is proposed to acquire in fee, all lands within the Guide Taking Line. The reservoir area will extend from the proposed damsite in the northwesterly direction along Phillips Brook in the Town of Westminster to a point about 500 feet south of the intersection of Route 12 and Jewel Hill Road in the southeasterly section of Ashburnham. The estimated project area is 620 acres,

including the areas of the damsite, borrow area access road, and construction area. Providing access to the 1-1/2 mile reach of stream below the dam will involve an additional 16 acres of land.

A spur road between Ashburnham Street and Bean Porridge Hill Road will be required. It will be constructed from a point on Route 12, about 1,600 feet south of the centerline of the dam, and will extend in a northerly direction beyond the westerly side of the abutment of the dam, connecting with Bean Porridge Hill Road. It will further service local traffic in the area.

The reservoir will be in a valley contained by gradual to steeply sloping wooded hillsides. At spillway crest, elevation 835 feet, m.s.l., it will be about 1.5 miles long.

The area on the easterly side of the valley is essentially underdeveloped, gradually sloping, lightly wooded, and open agricultural land. This area is sparsely developed, containing single family homes, potentially developable residential lands, and a few small marginal operated farms.

The area on the westerly side of the valley along existing Route 12 is for the most part a heavily wooded area, but includes some agricultural land.

There are 26 improved properties located within the project area. Located within the damsite and work area are two improved properties. One is an average size Cape-styled dwelling, and one capped-over residential foundation. Continuing upstream there is a poultry farm situated at the corner of Route 12 and Bean Porridge Hill Road, and two residential units.

Diagonally across Bean Porridge Hill Road, forming an intersection with Route 12 is Fred Smith Road, The properties to be acquired along this road are a poultry farm, two residential units, and a small industrial building.

Just north of the junction of Route 12 and Fred Smith Road is a large dairy farm which is the most valuable property in the project area. It consists of a two-story farmhouse, a large barn, silo, small barn, and several outbuildings.

Upstream from the farm is a small group of single family residential properties, which extend up to the vicinity of Dean Hill Road. From this area along Route 12 to the project's upper reaches are a group of small dwellings and seasonal type structures which have been converted into year-round residences, a small industrial plant, and a roadside restaurant. The remaining improved properties in the project area are situated on Dean Hill Road, and are in the newer construction category. Property values in this general area are slowly rising as evidenced by the number of new homes being constructed along paved roadways. For the most part, homesites are in demand which have choice road frontages, attractively located, and require a minimum amount of site preparation. This trend is expected to continue in a slow pace in the foreseeable future.

The 1.5 mile reach of stream below the dam is boarded by relatively undeveloped land containing four homes. The extent of access will be approximately 100 feet wide, including the brook, with the land varying between 20 to 40 feet each side of the stream banks. Present plans do not include taking easements or land from any of the four existing improved properties. The access strip, including the brook is equivalent to 16 acres at a total cost to the Government, including contingencies, etc., of $35,000 (based upon acquisition by fee). Wherever feasible, easements will be obtained in preference to acquisition. The extent of the easements and acquisition will be defined in DM No. 5, Real Estate, to be submitted at a later date.

68. Utilities. - Electric power and telephone systems are available to all properties within the proposed project area. Sanitary sewer facilities are provided by individual owners through the use of septic tanks or cesspool systems. Water is provided by individual owners by wells to all properties situated within the project area.

69. Zoning. - The Town of Westminster, presently, has no zoning regulations. All of the land situated in Ashburnham, that is within the project area, is located in an Agricultural-Residential District.

Area requirements within an Agricultural-Residential zone include a minimum of a 25,000 square foot lot having a 100-foot road frontage. There are no requirements specified for Commercial or Industrial zones.

70. Highest and Best Use. - The highest and best uses of the land within the project area are considered to be the present uses or as available for development.

71. Mineral Deposits. - Field inspections disclose no evidence of commercial mining of gravel nor the deposits of any minerals within the project area.

72. Crops. - The agricultural land in the project is devoted to the growth of hay, and pasture for cattle grazing. It is anticipated that there will be ample time to harvest these crops, and no special damages are estimated.

73. Timber. - A large portion of the land located within the project area is classified as wooded, and there are a few small stands of merchantable species. However, the quality and quantity are considered inadequate to require inclusion of any special allowance for merchantable timber. The value of the timber within the proposed reservoir area is reflected in the land values.

74. Water Rights. - An investigation of water rights to Phillips Brook revealed that there were no known special privileges other than riparian rights. The Commonwealth of Massachusetts allows riparian owners to make reasonable use of the water of a stream in connection with their riparian estate and for lawful purposes provided they leave the current diminished by no more than is reasonable.

75. Borrow Requirements. - About 42 acres of land will be required for impervious borrow. The 42 acres provide an area for a haul road to the damsite. The proposed borrow area is located about 3/4 mile south of the damsite on the easterly side of Bean Porridge Hill Road and the northerly side of Potato Hill Road. A set back of about 300 feet from both roads is proposed as a green belt area, as the owner who has recently puchased this site is in the process of developing the frontages with medium valued single family dwellings. Two are currently under construction. The set back of 300 feet will not interfere with the owner's present construction efforts. It is currently proposed to acquire this area in fee.

76. Relocations. - It is proposed to relocate a section of Route 12 which will require abandonment. It is proposed to relocate Route 12 along a new alignment commencing at a point approximately one-half mile south of Potato Hill Road, and will generally parallel the easterly boundary of the project and terminate at about 600 feet northerly of the Westminster Town Line. The alignment will cross Fred Smith and Dean Hill Roads, and will also traverse both wooded and cleared pasture land. About 38 acres will be required, including one residential unit. It is assumed that the telephone and electric power systems located along the existing Route 12 will be relocated within the relocated Route 12 right-of-way, and therefore, no lands are included in this report for this purpose.

77. Municipally-Owned Facilities. - Section III of the Act of Congress, approved 3 July 1958 (Public Law 85-500), authorizes the protection, alteration, reconstruction, relocation, or replacement of municipally-owned facilities. There are no structures or facilities located in the project area that fall within the purview of this Act.

78. Tax Loss. - The estimated loss for the taxes of Westminster and Ashburnham are based on current assessments and tax rates obtained from the town officials. Where partial takings will occur, the tax loss estimates are estimated on the average assessed values of the lands. Following is a summary of estimated tax losses applied to each town:

Westminster	$14,000
Ashburnham	1,000
Total Estimated Tax Losses	$15,000

79. Acquisition Costs. - Experience of this office in acquiring similar properties in other civil works projects in the area indicates that acquisition costs will average approximately $2,000 per tract. These costs include mapping, surveys, and legal descriptions, title evidence, appraisals, negotiations, closing, and administrative costs for condemnation. The number of ownerships within the Town of Westminster were computed from the local assessor's maps, and therefore, are considered reasonably accurate. There are no property maps nor assessor's maps

available in Ashburnham. The number of tracts affected by the project in this town were estimated by counting the number of improvements, and also through discussions with local officials. Based on this preliminary survey, the number of ownerships and acquisition costs are estimated as follows:

44 Ownerships	@	$2,000	=	$88,000

80. Reservoir Boundary Surveys and Markings. - Plans for surveying and marking project boundaries are required in all reservoir projects in accordance with existing regulations. The estimated costs are predicated upon experiences of this office in accomplishing this requirement in recent contracts in civil projects in this general area.

Current costs are estimated at $2,000 per mile. The perimeter distance of the subject reservoir is estimated at six miles; therefore, the costs for accomplishing this work is estimated as follows:

6 miles	@	$2,000	=	$12,000

81. Relocation Assistance. - Public Law 91-646, Uniform Relocation Assistance and Real Property Act of 1970, provides for a uniform and equitable treatment of persons displaced from their homes, businesses, and farms by Federal and Federally-assisted programs. In accordance with this law, an estimate of $360,000 is included in this report to cover the implementation of this Act.

82. Severance Damages. - Severance damages usually occur when partial takings are acquired and when the remaining portion may not be subject to full economic development. The severance damages are measured and estimated on the basis of "Before and After" appraisal methods and will reflect actual value losses incurred by remainders as a result of partial acquisitions. It is planned to follow good sound real estate acquisition practices so that damages of this nature will be minimized. The estimated severence damages for the entire project are $50,000.

83. Contingencies. - A contingency allowance of 15% is considered to be reasonably adequate to provide for possible appreciation of property values from the time of this estimate to

the acquisition date, for possible minor property line adjustments, or for additional hidden ownerships which may be disclosed by refinements of taking lines, for adverse condemnation awards, and to allow for actual, practical, and realistic negotiations pursuant to existing acquisition regulations.

84. Evaluation. - A thorough search of the records was made in both the Towns of Ashburnham and Westminster to obtain comparable sales data. In addition, real estate brokers, appraisers, local officials, and knowledgeable persons were interviewed to secure data and value estimates. The property evaluation is based on a knowledge of the general real estate market in this area which was obtained from this survey and analysis of sales data. All of the improvements located within the purchase area have been inspected from the exterior, and a random sample of interiors was inspected and owners interviewed. The land values used in this estimate are average unit values which reflect for both large and small tracts of land with differing physical characteristics.

The values assigned to developed lots include all land improvements. Potentially developable residential land consists of land fronting on the public roads with a potential for development in the foreseeable future. The value assigned is an average unit value which reflects for lots classified between poor to good. The land classified as wooded and cleared consists of poor land fronting on roads and rear lands.

The estimated real estate market values and total real estate costs are as follows:

NOOKAGEE LAKE

GROSS APPRAISAL

Improvements

20 Dwellings	(19 Homes 1 Capped Foundation)	$353,000
3 Farms		70,000
3 Commercial		58,000
TOTAL VALUE OF IMPROVEMENTS		$481,000

	TOTAL VALUE OF IMPROVEMENTS (Brought Forward)		$ 481,000
	Land		
30 Acres	Developed Residential Homesites @$3,500 Per Acre	$105,000	
30 Acres	Potential Homesites @$2,500 Per Acre	75,000	
5 Acres	Developed Commercial @$5,000 Per Acre	25,000	
40 Acres	Agricultural @$500 Per Acre	20,000	
492 Acres	Wooded & Cleared Land @$250 Per Acre	123,000	
17 Acres	Abandoned Roads & River Bottom	0	
6 Acres	Access Road @$500 Per Acre	3,000	
620 Acres	TOTAL VALUE OF LAND		$ 351,000
	Total Value of Land and Improvements		832,000
	Acquisition Costs		88,000
	Reservoir Boundary, Surveys and Markings		12,000
	Severance Damages		50,000
	Contingencies (15% of $982,000)		147,000
	Access to Stream Below Dam (16 Acres - incl. conting.)		35,000
	Relocation Assistance		360,000
	TOTAL ESTIMATED REAL ESTATE COSTS		$1,542,000
	Rounded To		$1,500,000

V. RELOCATIONS

85. Relocation and Effects. -

a. Roads. - Portions of the following roads with average daily traffic volumes of 20 - 3,540 vehicles (1969) are located within the reservoir area (See Plate 2-17). Actions to be taken for the portions of the roads involved are indicated below:

Road	Action
Route 12 (Ashburnham Street)	Relocated
Dean Hill Road	Regraded
Fred Smith Road	Regraded
Sheldon Road	Regraded
McIntire Road	Regraded
Bean Porridge Hill Road	Relocated (Spur Road)

A total of 3.9 miles of new roads will be required as a result of the project and includes relocations, raising or improvements. Approximately 2.5 miles will be abandoned. Massachusetts State Route 12 (Ashburnham Street) is the most heavily traveled highway in the reservoir area with a present day average daily traffic volume of 3,540 vehicles and is the major highway connecting Fitchburg, Massachusetts with Keene, New Hampshire.

b. Utilities. - Utilities in the reservoir area requiring relocation consist of electrical distribution and telephone lines.

c. Environmental Effect. - The relocated highway, Route 12, will be routed through undisturbed land and will have an adverse effect on the natural environment. The most important effect will be the destruction of about 23 acres of woodland and 15 acres of pasture land. Other adverse effects will be the creation of cut and fill slopes, the exposure of land areas to erosive action, and destruction of wildlife habitat represented by the 38 acres. The alignment of the new highway was selected, in part, by the wish to disrupt as small an area as possible. Relocation to the east, away from the proposed lake will provide for a wooded buffer zone between the proposed lake and traffic and also will provide land areas for recreation. All the exposed disturbed areas adjacent to the highway as well as the other roads will be topsoiled and seeded. Plantings of trees and shrubs will be provided where they will assist in enhancing the appearance of the modifications.

d. Views of Owners. - The plans for the proposed highway relocations and modifications as described herein have been reviewed with officials of the Massachusetts Department of Public Works, the towns of Ashburnham and Westminster, and the City of Fitchburg. All have indicated informally that they are in agreement with the proposed plans. The Westminster Selectmen have indicated that, although they approved of the relocation plans, this did not necessarily mean that they approved of the project. The owners of the utilities have indicated their concurrence.

86. Method of Accomplishment. -

a. Roads. - The changes in the road system, as affected by the reservoir, will be accomplished by the Government (as noted below) to conform with the geometric highway design standards of the Commonwealth of Massachusetts and Worcester County for existing traffic volumes (without traffic projections). Officials of the Massachusetts Department of Public Works have advised that they will design, acquire all land, award and superivse a construction contract for relocation of Route 12 under cost reimbursable contracts. The State's interest is limited to the relocation of Route 12 and its intersecting roads and does not include the spur road or road work to be performed during construction of the dam and reservoir. The latter work will be incorporated in the general contract for the dam. A lump sum contract will be executed with the Commonwealth of Massachusetts for design and preparation of contract plans and specifications for Route 12 relocation upon approval of DM No. 4, Relocations. Cost reimbursable contracts will be negotiated with the City of Fitchburg and the towns of Westminster and Ashburnham which will cover all required road modifications and provide for necessary legal expenses incurred in the abandonment of existing roads and acceptance of related roads. The estimated cost of relocating all roads including E&D and S&A is $1,555,000. All proposed road relocations and detailed cost estimates will be described in Design Memorandum No. 4 - Relocations.

b. Utilities. - The utility relocations will be accomplished by negotiated agreements with the owners; namely, the Massachusetts Electric Company, Ashburnham Municipal Light Department, and the New England Telephone and Telegraph Company. The compensation

to the owners will be based on replacement in kind, without betterment, or abandonment and removal where the service is no longer required, and will include furnishing engineering services, preparation of plans, and accomplishment of the required relocations, all of which are subject to the relocation procedure and approval of the Government. The total cost of utility relocations is tentatively estimated to be $95,000. All proposed utility relocations and detailed cost estimates will be described in Design Memorandum No. 4 - Relocations.

W. COST ESTIMATES

87. First Costs. - Unit prices used in estimated construction and relocation costs are based on average bid prices for similar work in the same general region, adjusted to the 1972 (July) price level. Valuations of real estate are based on recent appraisals of properties at the site and include the additional costs for resettlement and acquisition as required under the recently enacted Public Law 91-646. All construction costs include an allowance of 15-percent for contingencies. The total first cost of the project is estimated at $10,500,000. A summary of the cost of the various features of the work is given in Table 1, and a detailed breakdown of quantities and unit prices is included in Appendix D.

TABLE 1
SUMMARY OF PROJECT COSTS
(July 1972 Price Level)

Project Features	Estimated Cost
Lands and Damages	$ 1,500,000
Relocations	1,410,000
Reservoir	650,000
Dam and Appurtenant Structures	5,150,000
Roads	5,000
Recreation Facilities	15,000
Buildings, Grounds & Utilities	130,000
Permanent Operating Equipment	60,000
Engineering and Design	910,000
Supervision and Administration	670,000
Total Estimated Project First Cost	$10,500,000

88. Comparison of Estimates. - The current cost estimate of $10,500,000 shown in Table 1 reflects an increase of $2,100,000 since the last reported estimate in Appendix A of the Whitmanville GDM which amounted to $8,400,000. The 1972 estimate reflects more realistic costs than either the 1970 or the original 1964 estimate since it is based upon the availability of more accurate mapping, detailed surveys,more extensive explorations, refinements in designs and on more clearly defined requirements. A comparison of the estimates is shown in Table 2 and the major reasons for the changes are sited in a. and b. below.

TABLE 2

Project Feature	Authorized 1964	Previous 1970	Current 1972	Change 1970-1972
Lands and Damages	$ 375,000	$ 915,000	$1,500,000	$ 585,000
Relocations	750,000	1,100,000	1,410,000	310,000
Reservoir	95,000	160,000	650,000	490,000
Dam	3,033,000	4,760,000	5,150,000	390,000
Roads	13,000	20,000	5,000	-15,000
Recreation Facilities	162,000	-	15,000	15,000
Bldgs, Grounds, & Util.	62,000	60,000	130,000	70,000
Perm. Operating Equip.	-	35,000	60,000	25,000
Engineering & Design	580,000	780,000	910,000	130,000
Supervision & Admin.	360,000	570,000	670,000	100,000
	$5,430,000	$8,400,000	$10,500,000	$2,100,000

a. Escalation from 1964 to 1970. - The cost estimate of 1970 was based primarily on normal expected escalation of the 1964 price levels.

b. Changes from 1970 to 1972. -

(1) The Uniform Relocation Assistance Policy Act of 1970, Public Law 91-646, which authorized additional costs for resettlement and acquisition of real estate, increased the cost of lands for the reservoir and for the road relocations by approximately $375,000 of which $360,000 was attributed to reservoir lands and $15,000 for relocation lands.

(2) Approximately $216,000 of the $310,000 increase in cost for relocations is attributed to the cost of the spur road. The importance of providing the town with an acceptable connection between Bean Porridge Hill Road and Ashburnham Street was stated in Section G. The cost of $170,000 for the Route 12 climbing lane (1.6 miles long) was included in the cost increase from 1964 to 1970.

(3) The increase in cost of $490,000 for the item "Reservoir" is due primarily to the need for grubbing and stripping 150 acres of land in the reservoir to make the project aesthetically more pleasing and to insure a high quality of water. The concern for possible environmental degradation of the valley has been expressed on several occasions by various groups. Their concern was underscored by the letter from the Governor dated 23 July 1971, Exhibit C-6.

(4) Concern for the environmental impact of the project, particularly during construction, has indirectly influenced the cost. Restrictions on the contractor's operations in the borrow area, the selection of the haul road, sequential clearing and stripping, disposal of trees, erosion control, etc., have decidedly influenced construction costs.

(5) A cost escalation since the previous estimate of 15% due to higher costs of labor and materials, is accountable for part of the increase in the total cost of the project.

X. SCHEDULE FOR DESIGN AND CONSTRUCTION

89. Design. - Preparation of plans and specifications for the relocation of Route 12 will be essentially completed in December 1974; the earliest that the Commonwealth of Massachusetts can complete the design. Preparation of plans and specifications for the dam and appurtenant structures will be designed concurrently with the highway design and will also be completed in December 1974.

90. Construction. -

a. Relocations. - Route 12 passes through the damsite, therefore, its relocations must be initiated early in the construction program in order to clear the work area for the construction of the dam. Construction of the relocated road will be initiated in the early spring and completed in the fall of the following year (2nd half Construction Fiscal Year One thru 1st half of Construction Fiscal Year Three). The work for the relocated highway will be accomplished under a contract administered by the Commonwealth of Massachusetts. Construction of the relocation of electric distribution and telephone lines will be accomplished under separate contracts to be negotiated with the respective utility companies in Fiscal Year One.

b. Dam and Appurtenant Structures. - Construction of the dam outlet works, spillway and clearing of the reservoir will be accomplished under a single continuing contract to be awarded late in Construction Fiscal Year Two when the highway relocation has progressed to an advanced stage of completion. An estimated construction schedule follows:

(1) First Season of Dam Construction. - During the remainder of the construction season (Remainder of Fiscal Year Two and 1st half of Construction Fiscal Year Three) the contractor will mobilize and initiate construction of the spur road and complete the clearing and grubbing of the sites of the structures and a segment of the borrow area and initiate excavation of the outlet works.

(2) Second Season of Dam Construction (2nd half Fiscal Year Three and 1st half Fiscal Year Four Construction Seasons). - The contractor will complete the excavation of the outlet works and by

1 June must complete the inlet and outlet channel, the intake tower to an elevation above the permanent cofferdam, the conduit, the stilling basin, place the impervious blanket, and initiate excavation of the spillway discharge channel. He will construct by 1 July temporary cofferdams upstream and downstream of the damsite and divert Phillips Brook through the outlet works. After the diversion has been completed, the contractor will strip the remainder of the damsite, construct the permanent cofferdam to Elevation 790.0 and initiate and complete the foundation grout curtain to Elevation 800 by mid-November. The contractor will also continue as needed the excavation of the spillway channel and use the rock as protection on the cofferdam.

(3) Third Season of Dam Construction (2nd half Fiscal Year Four and 1st half Fiscal Year Five Construction Season). - With return of favorable weather, the contractor will continue with placement of the embankment fill, excavation of the spillway channel; complete the grout curtain above El. 800, complete the construction of the intake tower and the placing of the spillway concrete. The borrow area will be topsoiled and seeded in phases as material excavation progresses.

(4) Fourth Season of Dam Construction (2nd half Fiscal Year Five Construction Season). - The clearing and stripping of the reservoir, will be completed as will be the buildings. The service bridge will be constructed and the remainder of the earth slopes will be topsoiled and seeded. All work is expected to be completed by 30 June (Fiscal Year Five).

91. Funds Required. - Funds will be required by fiscal year approximately as follows:

Construction Fiscal Year	Amounts Required
1	$ 400,000
2	2,400,000
3	2,600,000
4	3,200,000
5	1,161,300
Sub Total	$ 9,761,300
Allotted thru FY 1973	738,700
TOTAL PROJECT ESTIMATE	$10,500,000

Y. OPERATION AND MAINTENANCE

92. General. - The Nookagee Lake project will be operated and maintained by the Federal Government under the supervision of the Division Engineer, Corps of Engineers, Waltham, Massachusetts. A project manager and an assistant will be required to operate and maintain the project complex.

93. Operations. - The reservoir will be regulated for flood control and water quality control by the Corps of Engineers including the minimal recreational facilities. Operational details are outlined in Section Z, Reservoir Regulation, of this report.

94. Maintenance. - Periodic inspection will be made of the Nookagee Dam and appurtenant structures and equipment. The dam and appurtenant structures will be maintained and operated by a Corps of Engineers staff. Maintenance will be based on regular detailed inspection of the entire works, including all operations necessary to preserve the structures.

95. Major Replacements. - Items deemed to have a useable life less than that of the project will be replaced when necessary. Most items such as flood control gates, gate valves, heating and ventilation systems, instrumentation equipment and part of the recreational facilities are considered to need replacement every twenty-five years.

96. Annual Costs. - Estimated annual cost of major replacement is $6,000. The Estimated annual cost of operation and maintenance is $54,000 and includes:

Salaries	$21,000
Reservoir Cont. Center	8,000
Real Estate	4,000
Utilities	5,000
Supplies & Misc.	4,000
S & A	3,000
Division Overhead	9,000
TOTAL	$54,000

Z. RESERVOIR REGULATION

97. General. - Flood control and water quality discharges from the project will be regulated by the Corps and will be coordinated with releases from Whitmanville Lake, which is also under design. In addition, flood releases from the project will also be coordinated with releases from Phillips Dam, which is authorized but not yet under design. The allocation of the total storage of 8,400 acre-feet for Nookagee is summarized in Paragraph 51 and in Figure 2 of this memorandum.

98. Regulation Procedures. -

a. Flood Control. - Nookagee Lake discharges will be regulated primarily to prevent or reduce flood flows on the North Nashua River in Fitchburg and Leominster, and secondarily, for other downstream communities on the Nashua and Merrimack Rivers. During construction of the project the Reservoir Control Center of the Water Control Branch will establish detailed regulation procedures. Information on time of emptying and downstream channel capacities for the Nookagee and Whitmanville projects were presented in DM No. 1 - Hydrology (Revised). The channel capacity of the North Nashua River through the existing local protection project in the downstream area of Fitchburg was originally designed for 9,000 c.f.s. Deterioration over the past 30 years has reduced channel capacities at some locations to below 6,500 c.f.s. Gages, either recording or staff, will be installed at selected downstream locations and will be used in determining operating criteria.

The effect of the proposed reservoir system on the record March 1936 flood is shown on Plate 1-24 of the Hydrology DM. The routing of the standard project flood through the Whitmanville and Nookagee Lakes is also presented on Plates 1-17 and 1-22. The effect of the proposed reservoir system on the standard project flood in Fitchburg is shown on Plate 2-13 of this memorandum.

b. Water Quality - Recreation. - By the end of the spring snowmelt season in March or April, a full water quality pool will be established. Snow courses will be established upstream of the

reservoirs in order to monitor the water content and density of the snowpack. In order to stabilize the summer recreation pool at Whitmanville to the fullest extent possible, it is contemplated that all necessary water quality releases for the period June thru Labor Day would be made from the 3,000 acre-feet of water quality storage at Nookagee Lake. After Labor Day these releases would be stopped and water quality releases from Whitmanville will commence. A minimum flow of about 2 c.f.s. will always be released from the Nookagee project as recommended by the U. S. Fish and Wildlife Service. The water quality storage will be refilled as rapidly as possible, after Labor Day, while maintaining minimum flow in the stream.

99. Recording Equipment and Gages. - A pool stage recorder will provide a continuous record of the water level upstream of Nookagee Lake, and a tile gage will also be used for reading pool levels and for calibrating the recorder. A tailwater recording gage will measure both high and low flow reservoir releases.

A recording gage, established by the USGS on the North Nashua River in Fitchburg near the Arden Mill Dam will measure stream flow and will be used as a primary index station for flood control and for water quality releases from Nookagee and Whitmanville Lakes. Other gages, either recording or staff will be installed, as needed, at selected downstream index stations.

Permanent water quality monitoring equipment will be installed at Nookagee and Whitmanville Lakes and also at the Fitchburg gage to measure various water quality parameters. These parameters will include dissolved oxygen, water temperature, P^H, conductivity and other chemical, physical and bacteriological parameters as may be deemed necessary. Evaporation pans will be located at the project to measure evaporation.

100. Communcation. - In order to assure continuous contact between the operating personnel at the dam and the Division Office at Waltham, Massachusetts, telephone and radio equipment will be installed in the utility building and remoted to the operating room. River stage data from the Leominster gaging station and the water quality data from the Fitchburg gage will be directly transmitted to the Reservoir Control Center.

AA. HEALTH CONTROL

101. Existing Pollution Health Hazard. - Serious pollution exists in the North Nashua River from the outfall of the uppermost paper company in Fitchburg to its confluence with the Nashua at Lancaster. The industrial and domestic pollution not only inhibits the potential uses of the water but is a serious health hazard to the inhabitants of the basin. In December 1968, the Northeast Region of the Federal Water Pollution Control Administration issued a five part report on the pollution of the Merrimack River and certain tributaries and in the course of summarizing stated that the "excessive bacterial pollution presents a health hazard to all who come in contact with the water". Conversely, Phillips Brook is of high quality and free of pollutants.

102. Vector Problem. - Based upon conversations with the Regional Office of the U. S. Public Health Service and the Environmental Health Division of the Massachusetts Department of Public Health, it is understood that there are no published reports on the vector hazards of the Merrimack River Basin. A summary of the information available concludes that the vector problem can be divided into two groups: Vector-Borne Diseases and Vector-Annoyance Problems.

a. Vector-Borne Diseases. - The two vector-borne diseases of potential importance in the Merrimack River Basin include the viral encephalitis and Rocky Mountain spotted fever. The "Eastern" type of mosquito-borne encephalitis does appear in Massachusetts and during the period 1938-1968, 50 cases occurred in Eastern Massachusetts. Although cases of Rocky Mountain spotted fever (transmitted by the American dog tick) have been reported on Cape Cod, no occurrence of this disease has been reported from the Nashua River Basin.

b. Vector-Annoyance Problems. - The vector-annoyance problems, although not a serious public health problem, can cause much annoyance and discomfort. Within the Nashua River Basin, the common annoyances include mosquitos, black flies, the deer and horse flies.

c. Control. - To minimize the vector problem for the Nookagee Lake project, consultation with the U. S. Public Health Service and the Commonwealth of Massachusetts will be pursued and specific recommendations will be requested.

BB. POLLUTION CONTROL

103. General. - The water in Phillips Brook is of high quality and a distinct asset to the basin. In addition to providing recreational enjoyment, the Brook is a source of process water (3/4 m. g. d.) for a paper mill located in the vicinity of the confluence of Phillips Brook and the North Nashua River, (Exhibit 8, Sheet 2, Appendix A of Whitmanville GDM). Consequently, Phillips Brook must be kept as free of pollutants as possible both during and after construction. To achieve the pollution control necessary, control measures will be included in the design of the project. Possible sources of pollution and their control are discussed below.

104. Possible Sources of Pollution. - Water, air, and noise pollution are possible from the following sources:

a. Soil erosion

b. Dust

c. Clearing and stripping

d. Borrow operations

e. Spoil from batch plant or concrete placing

f. Concrete curing water (Spillway, etc.)

g. Operation of motorized equipment

h. Oil and fuel spillage

i. Contractor storage and equipment maintenance areas

j. Personnel sanitation facilities

105. Pollution Control Measures. - Measures to be employed to minimize pollution include:

a. Soil Erosion. - Erosion of soil by water is a recognized problem. The disadvantages of uncontrolled water erosion include

pollution by water borne soil material, destruction of land surfaces and vegetation, and unfavorable working conditions. It is foreseen that precautions must be taken during dam construction to avoid unnecessary destruction of stabilizing vegetation control surface runoff, and provide settling basins to remove silt from water before it is discharged into the stream.

b. Dust. - Since dust can become a pollution problem, especially in dry weather, a program making use of water and dust palliatives will be enforced on the project.

c. Clearing and Stripping. - Clearing on the project will be kept to the minimum necessary. Burning of cleared material will not be allowed. All trees will be cut into sawlogs and cordwood, with smaller material processed by woodchippers. The best possible means of disposing of the material will be studied during design.

The problem of preventing surface erosion during stripping operations and while the reservoir is being filled has been considered. One solution is to strip in increments defined by two contour lines. When the area increment is stripped, the reservoir water level would be raised to cover it. In this manner, no large area would be subject to surface erosion. This and other methods will be studied during design.

d. Borrow Operations. - Pollution by waterborne silt is always a problem in borrow operations. Several methods are under consideration to minimize the problem. A technique will be studied and resolved during design to control surface water runoff. Water will be collected, channeled to settling basins where silt can be removed at zero or low velocities, and the water discharged to the stream.

To avoid exposure of excavated earth surfaces to water erosion for longer periods than necessary, a sequential borrow operation will be planned. By this method, certain limited areas will be cleared, stripped, excavated, graded and revegetated in a series pattern. Thus, the disadvantages of waiting until all borrow operations are complete before stabilization of earth surfaces will be avoided, and both excessive water erosion and unnecessary dust pollution avoided.

e. Concrete Spillage. - Since some spillage of concrete can be expected from concrete placement operations, it is recognized that a method of containing such material will be necessary in order to prevent it from entering the river. Probably a system of small dikes and a regular cleanup operation will be necessary.

f. Concrete Curing Water. - Disposal of water used in concrete curing is a recognized problem, and since it can carry materials in suspension which could adversely affect water quality in the Phillips Brook a method of controlling it must be worked out in final design.

g. Operation of Motorized Equipment. - Pollution by noise and exhaust emissions is to be expected from operation of equipment. In order to minimize such pollution, a continuing program will be in effect during construction to insure that all engines are properly tuned, that effective mufflers are installed in all equipment, and that correct grades of fuel are used in the engines.

h. Oil and Fuel Spillage. - All necessary precautions will be taken to insure that oil and fuel are not disposed of carelessly, and to insure that the river and/or ground is not polluted by these agents. A strict policy will be enforced requiring that all major equipment maintenance be performed in a predetermined location, that all used oils be placed in containers for proper disposal, and that fuel and oil spillage on the ground be kept to a minimum.

i. Contractor Storage and Equipment Maintenance Areas. - The locations of these areas will be designated by the Government. Grading and drainage will be controlled to prevent surface runoff from carrying pollutants and debris into the river. A policy of dust control will be enforced.

j. Personnel Sanitation Facilities. - Strict sanitation measures will be enforced. The contractor will be required to construct facilities for sanitation and for proper disposal of sewage. As needed, portable pumpout type facilities will be required on the project site.

k. Downstream Stilling Basin. - During design, it will be necessary to evaluate the effectiveness of pollution control measures

related to water quality. If it is found that there is a significant possibility that there may be pollutants escaping the control measures described above, consideration will be given to the necessity for construction of a stilling basin downstream of the construction area to trap such escaping pollutants.

CC. BENEFITS

106. General. - The North Nashua River Basin drains the north-central part of Worcester County, the largest county in Massachusetts. Representing slightly less than 10-percent of Worcester County in area, the basin includes the Fitchburg-Leominster SMSA (Standard Metropolitan Statistical Area) one of three economic nodes which dominate an otherwise almost rural county. The other nodes are the Worcester SMSA and the Webster-Dudley-Southbridge area in the southern end of the county. The Fitchburg-Leominster SMSA lies entirely in the basin.

a. Economy. - Manufacturing is the largest single employer in the basin and the Fitchburg-Leominster area is not only a major manufacturing center, but is also the wholesale and retail trade center for northern Worcester County, adjacent portions of Middlesex County and a part of southern New Hampshire. With 150,000 people living within 15 miles of the center of the SMSA and having a reasonably good road network, the area has developed into a regional market-place surpassed only by the Worcester SMSA in size and sales volume.

b. Population. - The basin had a population of 98,860 in the 1970 Census. In the decade 1960-1970, population grew 9.9% compared with 9.4% for the state and 8.7% for Worcester County as a whole. Its gross density of 748.9 people per square mile is slightly higher than that of the state as a whole (715.6/ SM) and 79% higher (418/SM) than Worcester County.

107. Flood Control Benefits. -

a. Flood Loss Potentials. - Over 2,800 acres of land lying along both banks of the North Nashua River and its tributaries are

subject to flooding. In its lower reaches the flood plain is largely unused, but above Mechanic Street Bridge in Leominster it is increasingly built over as one travels upstream. Above the Fitchburg-Leominster City line the only portion of the river banks not developed is that occupied by the Fitchburg Airport. Much of Fitchburg's industrial plant and a portion of the commercial center of the city are in the flood plain.

A recurrence of the flood levels of March 1936, the record flood in the basin, would cause losses estimated at over $42.2 million under 1972 conditions. The authorized plan for flood protection, comprised of four reservoirs and three channel improvement projects, would prevent $41.8 million of this recurring damage. Nookagee Lake acts as an integral unit in this coordinated system for reduction of flood flows in the basin (see Table 3). Much of the loss would be to industrial properties but commercial and public interests including the airport and the Leominster sewage treatment plant would also be involved.

Prior to the preparation of the Whitmanville and Nookagee Lake GDM's, the flood losses in the basin were reviewed in the field to ascertain the relevancy of the 1963 damage estimate of $1,280,600. The review concluded that the original estimate remained essentially valid and warranted only a price level adjustment. Under current conditions the annual losses in the basin are estimated at $1,570,000.

b. Trends of Development. - As noted above, the population of the basin over the past decade, has grown at a rate exceeding that of the State and Worcester County. Field reconnaissance indicates that the loss potential in the flood plain has grown at an even faster pace since 1962 as new development has taken place in Leominster. Historic trends in flood losses in New England indicate an increase in the loss potential in developed or partly developed areas with the passage of time. This is especially true with industrial properties where the need to stay competitive means increasingly sophisticated plant but it is also true for commercial properties. Part of the increase in flood loss potential is due to additions to existing properties, part is due to increased values of contents in structures (such as color television sets replacing black and white sets) and part is due to new construction. All these items

TABLE 3

NORTH NASHUA RIVER BASIN

July 1972

Damage Prevention Data on
Recurrence of Record 1936 Storm Levels

	North Nashua River	Baker Brook	Monoosnoc Brook	Total Basin
Recurring Losses	$40,530,000	$180,000	$1,490,000	$42,200,000
Damages Prevented	(40,210,000)	(130,000)	(1,460,000)	(41,800,000)
North Nashua Channel Improvement) Whitmanville Lake) Nookagee Lake) Phillips Reservoir)	40,210,000			
Baker Brook Channel Improvement (Inactive)		130,000		
Monoosnoc Channel Improvement) Monoosnoc Lake) (To be Restudied)			1,460,000	
Residual Losses	(320,000)	(50,000)	(30,000)	(400,000)

are related to the real wealth of an area. Wealth, expressed as personal income, has been projected to increase approximately 6.5 times, measured in constant 1958 dollars, over the next 50 years for the water resources area of the basin. Nookagee Reservoir is expected to be operational in 1978-1979, however, since data was already available 1975 has been taken as the base year in making projections. The increase for intermediate bench mark years are as follows:

1980	1.184 times 1975 base
2000	2.504 times 1975 base
2020	5.267 times 1975 base
2025	6.070 times 1975 base

Growth between bench mark years was assumed to be a straight line. Flood losses are projected to increase at a rate which is 40% of the increase in personal income. Discounted at 5-1/2% the average annual equivalent value of the growth amounts to 0.550. Annual losses and benefits were adjusted by this factor to reflect the expected growth. Total estimated annual losses amount to $2,434,000 consisting of $1,570,000 to present development and $864,000 average annual equivalent losses due to growth.

In selecting a rate for projection of losses and benefits cognizance was taken of the rates suggested in the North Atlantic Region report, Appendix E. The report states that from 0.66 to 0.74 of the increase in personal income was reasonable in the North Atlantic Region. These rates are deemed high for southern New England where a rate of 0.40 appears to be more appropriate and was therefore used.

c. Annual Flood Damage Prevention Benefits. - Annual flood damage prevention benefits were measured as the difference between annual losses in the basin after the restoration of the North Nashua River channel in Fitchburg and annual losses remaining after the operation of a system of three reservoirs, Nookagee, Whitmanville and Phillips Dam with each reservoir receiving an

equitable share of the benefits. Benefits to Nookagee in the system amount to $730,000 consisting of $465,000 to present development and $265,000 average annual equivalent benefits due to future growth. If Nookagee is considered as acting alone the benefit would be $780,000 and as last added, for the most stringent economic test the benefit would be $450,000.

108. Water Quality Control Benefits. - Both low flow augmentation and adequate treatment of wastes at their source are essential to meet water quality objectives in the North Nashua River. Benefits from the resulting water quality will be widespread and will include improved public health, more attractive communities, enhanced real estate values, a better aquatic environment, attraction of new industries, better recreational opportunities, and an upgrading of the general economy of the region.

The most feasible alternative method of achieving water quality control in the North Nashua River is a single purpose dam and reservoir at the Nookagee project site which would provide water storage for streamflow regulation. The cost of a single purpose water quality control dam and reservoir affords a measure of the minimum value of the benefits to be derived from flow releases.

For the entire North Nashua Reservoir system the total water quality benefits amounting to $573,000 have been equated to the annual cost of a single purpose dam at the Nookagee site which would provide equivalent storage. Since the Whitmanville Lake project would contain 800 acre-feet (21%) of the total 3,800 acre-feet of the required augmentation, 21% of the total benefits ($120,000) was therefore accredited to Whitmanville Lake, and the balance $453,000 was accredited to the Nookagee Lake project.

109. Recreational Benefits. - Statistics available from BOR indicate that there is an enormous, unsatisfied demand for water-based recreation in Massachusetts. In addition, the latest State Recreation Plan recognizes the importance of the proposed Corps lakes in the North Nashua River Basin for recreational pursuits.

The State's Department of Natural Resources recently stated "the opportunity to create alternative recreation developments on all other existing lakes is remote since single-purpose projects would not benefit from the economies inherent in a multi-purpose flood control development. Also, experience has proven that it is extremely difficult to obtain even a public boat ramp on great ponds in this vicinity much less a state park development. Lake Winnekeag is a prime example of the difficulties encountered in obtaining public use of lakes with existing private shorefront development".

The recent construction of Interstate 495 through the area, the planned construction of a north-south highway from Worcester to Fitchburg and the improvement of Route 2 will assure easy access to the North Nashua region from the major metropolitan areas of Worcester, Lowell and Boston.

For reasons cited in the reformulation study, the Whitmanville Lake site was deemed to be more ideally suited for the more extensive and varied recreational development. At the request of the State, the Nookagee site will emphasize fishing, whereas other pursuits such as water skiing and motorboating will not be encouraged. By providing access to the reach of the brook below the dam, the Nookagee site will feature both stream fishing as well as lake fishing. Even during the driest summers the water quality control releases will insure an abundant supply of high quality water and will extend the stream fishing season as much as two months.

The 1.5 mile reach of stream below the dam is boarded by relatively undeveloped land containing four homes. The extent of access will be approximately 100 feet wide, including the brook, with the land varying between 20 to 40 feet each side of the stream banks. Providing access to the reach of stream below the dam will help to mitigate the loss of 1-3/4 miles of stream due to inundation. Present plans do not include taking easements or land from any of the four existing improved ownerships. The access strip, including the brook is equivalent to 16 acres at a total cost to the Government, including contingencies, etc., of $35,000.

By providing public access and boat launching areas, it is estimated that the lake will provide an average annual utilization of 11,300 fisherman-days for a net recreational benefit of $34,000. Stream fishing below the dam will improve to the extent of providing an additional 2,000 fisherman-days and will mitigate the loss of 2,000 fisherman-days from the inundated stream.

The loss of wildlife habitat in the reservoir area will be mitigated by the creation of shallow water areas which would be utilized by waterfowl. Nature study and bird watching will result in an average annual recreational benefit of $200 (considered insignificant).

DD. COST ALLOCATION

110. Allocation of Costs Among Purposes. - Costs of the multiple purpose dam and lake allocated to the purposes of flood control, water quality control and recreation were made by the Separable Costs Remaining Benefits method. A detailed breakdown of allocations among project purposes is shown in Appendix D. A summary follows:

Purpose	First Cost	Annual Charges
Flood Control	$ 5,700,000	$368,000
Recreation (limited)	270,000	23,000
Water Quality Control	4,530,000	297,000
TOTAL	$10,500,000	$688,000

111. Apportionment of Costs Among Interests. - Since the recreational facilities will be minimal and the benefits for flood control and low flow augmentation are widespread, all costs for the Nookagee Lake Project are Federal. The Federal cost will include the first costs, annual charges and annual operations, maintenance, and replacement costs. A detailed breakdown of apportionment is, therefore, not necessary.

EE. RECOMMENDATION

112. Recommendation. - The Nookagee Lake project plan is the second installment of the implementation of the water resources plan for the North Nashua River Basin. It is recommended that the project plan (as reformulated) consisting of an earthfill dam, reservoir and appurtenant structures, to be located on Phillips Brook in Westminster, Massachusetts, and providing multiple-use storage for flood control, water quality control and limited recreation, as submitted in this Memorandum, be approved as a basis for preparation of detailed Design Memoranda and contract plans and specifications.

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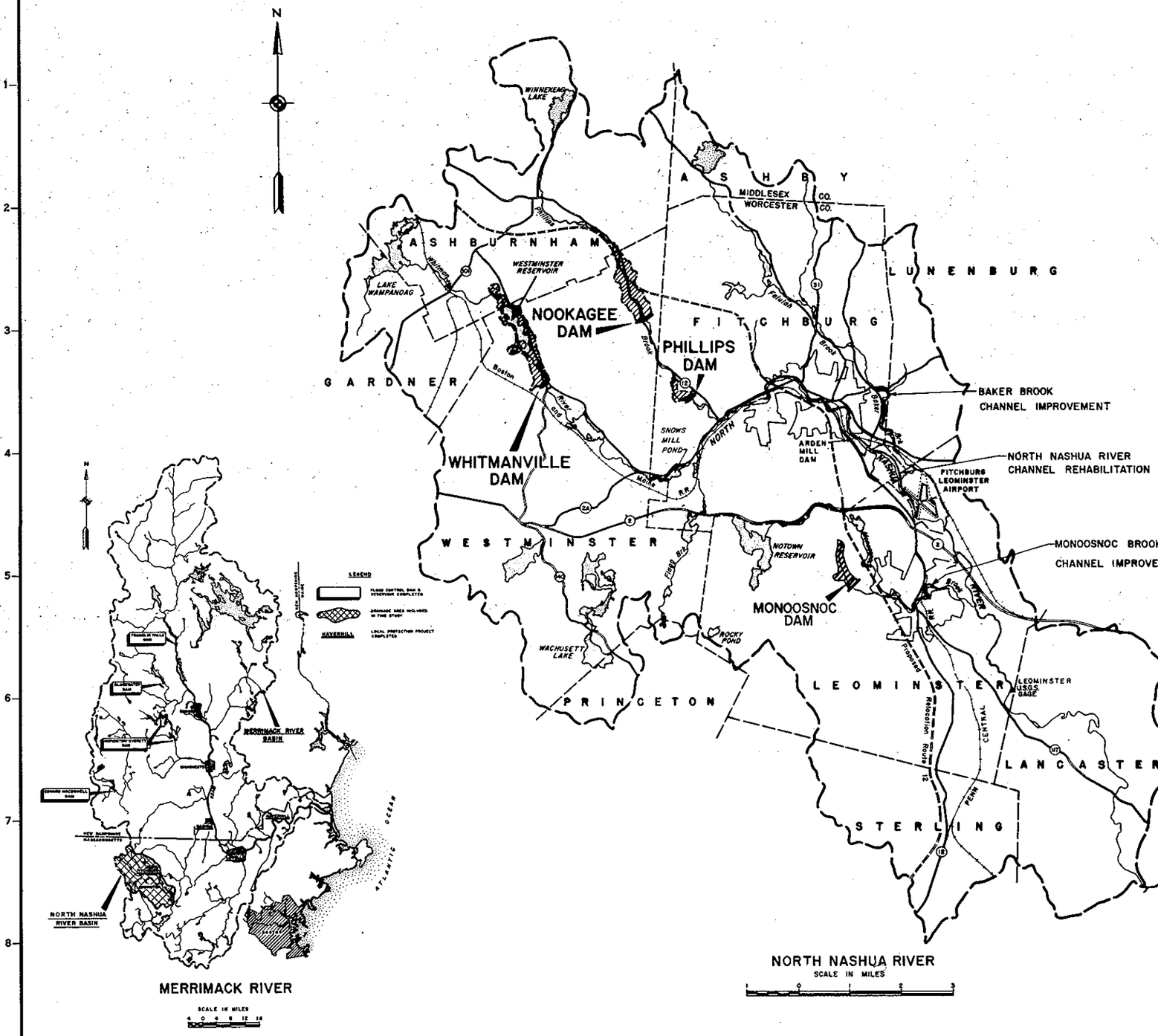

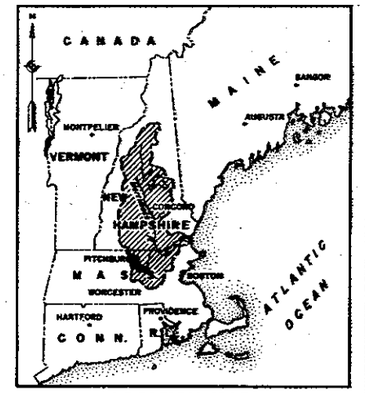

LOCATION MAP

SCALE IN MILES
25 0 25 50 75 100

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY

PROJECT ENGINEER

SUBMITTED BY — CHIEF, PLANS & RPTS BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
WATERSHED MAP
PHILLIPS BROOK MASSACHUSETTS

APPROVED — DATE

CHIEF, ENGINEERING DIVISION

SCALE AS SHOWN

DRAWING NUMBER

PLATE 2-1

CORPS OF ENGINEERS

U. S. ARMY

A B C D E F G H

N 594 000 E 502 000 N 592 000 N 590 000 E 504 000 N 588 000 N 586 000 E 506 000 N 584 000

E 500 000 E 498 000 E 496 000

1 2 3 4 5 6 7 8

RELOCATED ROUTE 12

FLOW LINE AT SPILLWAY
CREST EL. 835.0

OVERLOOK AREA

SPILLWAY

JEWELL HILL ROAD

ASHBURNHAM WESTMIN STER

DEAN HILL ROAD

MAIN STREET

ASHBURNHAM

FRED SMITH ROAD

PHILLIPS BROOK

STREAM

BEAN PORRIDGE HILL RD

FITCHBURG WESTMIN STER

JEWELL RD

McINTIRE RD

SPUR ROAD

DAM
TOP EL. 846.5

BORROW AREA

FLOW LINE
WATER QUALITY POOL
EL. 816.0

FLOW LINE AT SPILLWAY
CREST EL. 835.0

NOTES:
1. 2000 FT. GRID BASED ON MASS. RECTANGULAR COORDINATE SYSTEM
2. DATUM IS MEAN SEA LEVEL 1929

POTATO HILL RD

RESERVOIR PLAN
SCALE: 1"=400'

GRAPHIC SCALE
1"=400' 400' 0 400' 800'

SAFETY PAYS

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
RESERVOIR PLAN
PHILLIPS BROOK MASSACHUSETTS

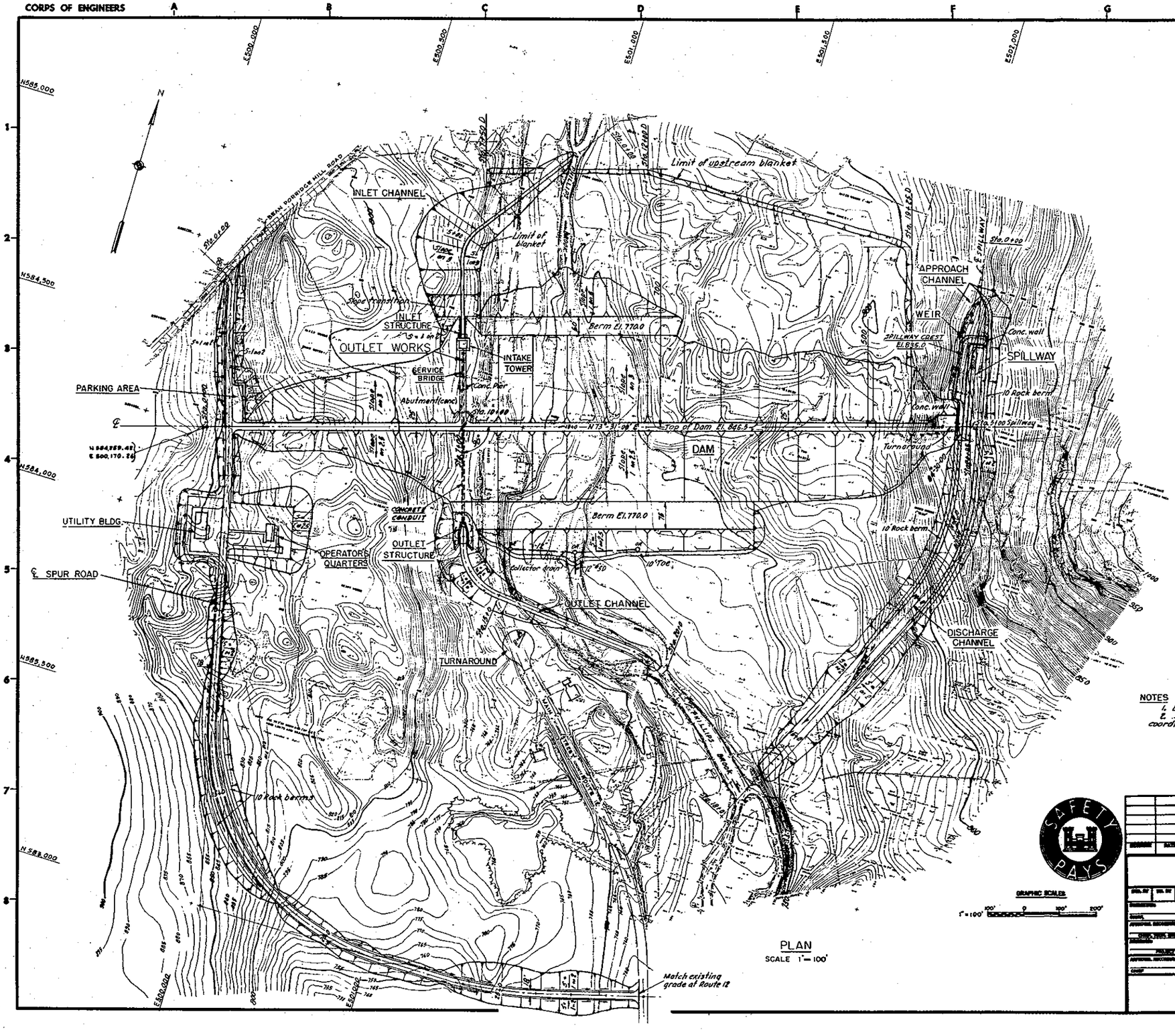
APPROVED DATE

CHIEF, ENGINEERING DIVISION

SCALE SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 2-2

CORPS OF ENGINEERS — U. S. ARMY



PLAN
SCALE 1" = 100'

NOTES
1. Elevations refer to Mean Sea Level Datum.
2. 500 ft. grid based on Massachusetts rectangular coordinate system.

GRAPHIC SCALE
1" = 100'

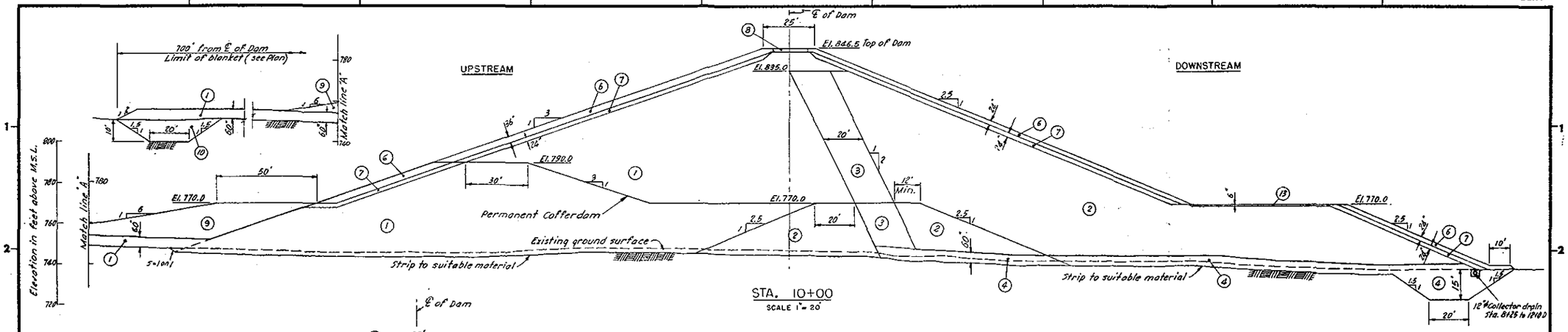
SAFETY PAYS

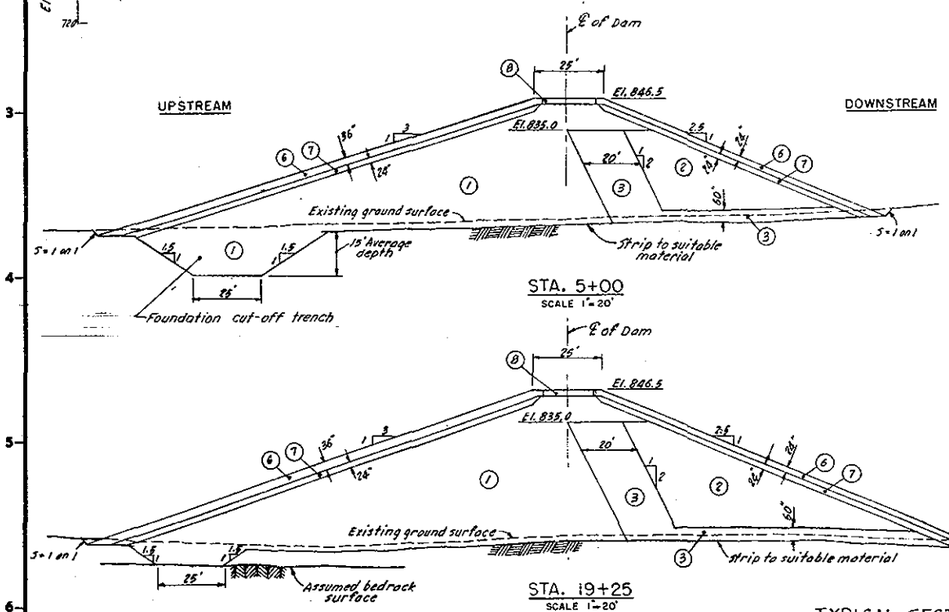
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
GENERAL PLAN
PHILLIPS BROOK — MASSACHUSETTS

PLATE 2-3

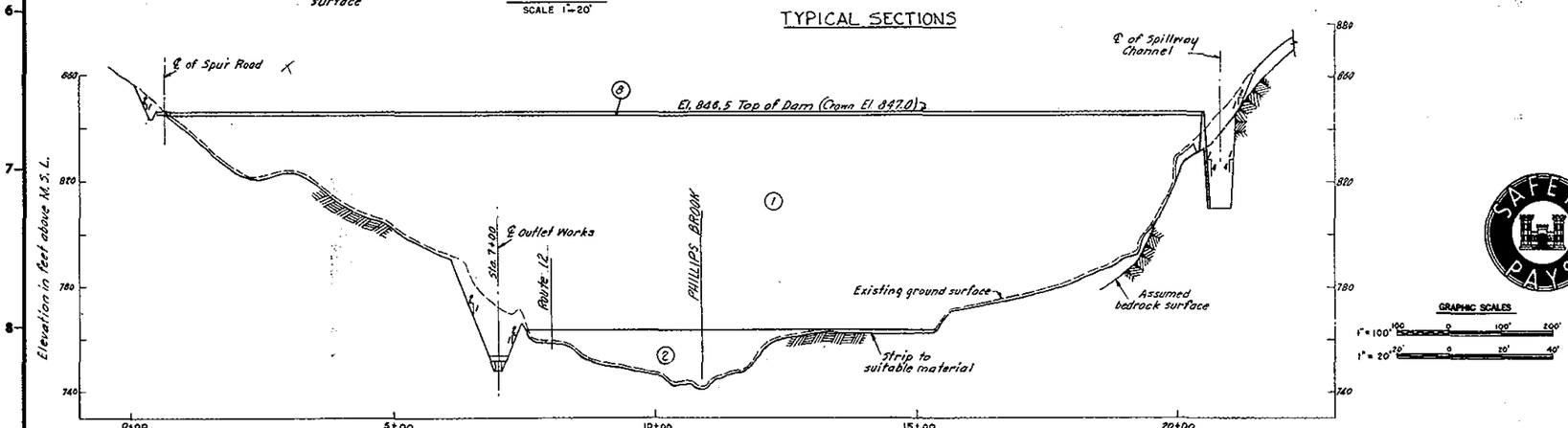
CORPS OF ENGINEERS A B C D E F G H U. S ARMY





LEGEND — MATERIALS	
DESIG.	TYPE
(1)	Compacted Impervious fill.
(2)	Compacted Random fill.
(3)	Compacted Pervious fill.
(4)	Compacted drainage fill.
(5)	Omitted.
(6)	Rock slope protection.
(7)	Gravel bedding.
(8)	Compacted Road Gravel.
(9)	Spoil fill.
(10)	Uncompacted Impervious fill.
(11)	Compacted Gravel backfill.
(12)	Compacted Impervious backfill
(13)	Topsoil, seeded.

TYPICAL SECTIONS



GRAPHIC SCALES
1"=100' 100 0 100' 200'
1"=20' 20' 0 20' 40'

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

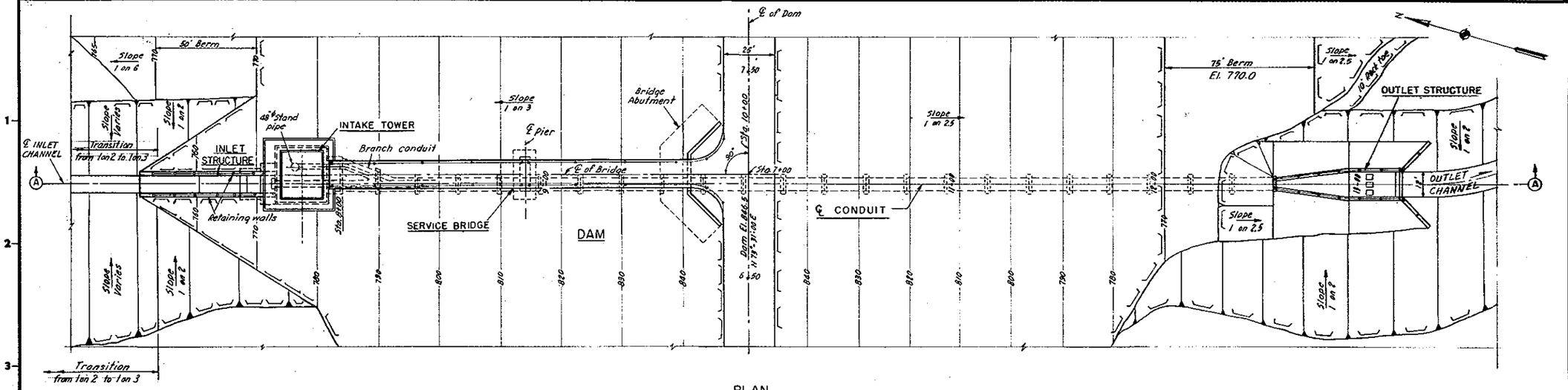
DES. BY | DR. BY | CK. BY
SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECH. EXEC. BRANCH
RECOMMEND
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
DAM EMBANKMENT
PROFILE AND TYPICAL SECTIONS
PHILLIPS BROOK MASSACHUSETTS
APPROVED DATE
CHIEF, ENGINEERING DIVISION

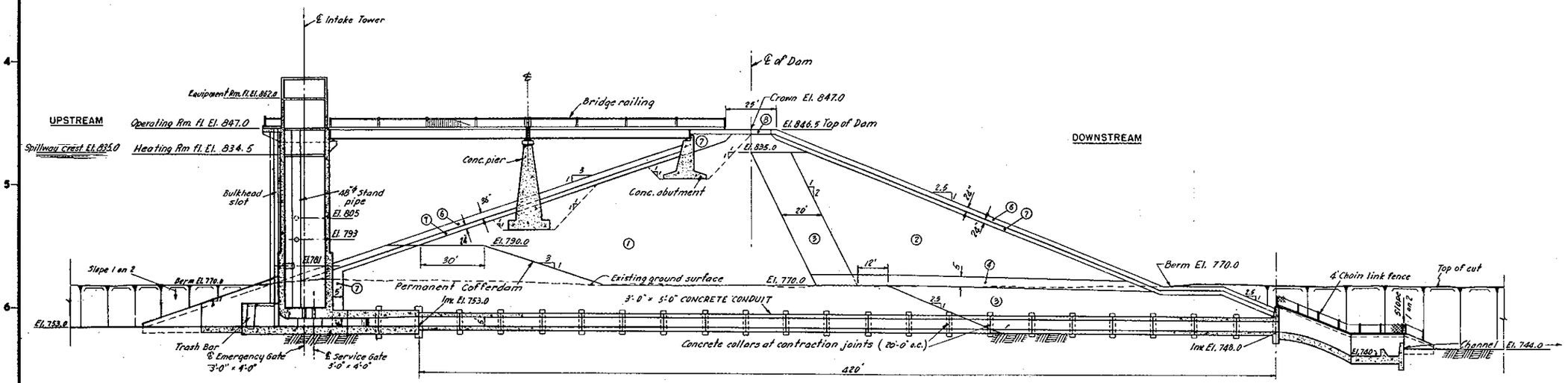
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 2-4

CORPS OF ENGINEERS — U. S ARMY



PLAN
SCALE 1"=20'



SECTION A--A
SCALE 1"=20'

NOTE:
For Legend-Material, see Plate 2-4

GRAPHIC SCALES
1" = 20' 0 10' 40'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
OUTLET WORKS
PLAN AND SECTION

PHILLIPS BROOK — MASSACHUSETTS

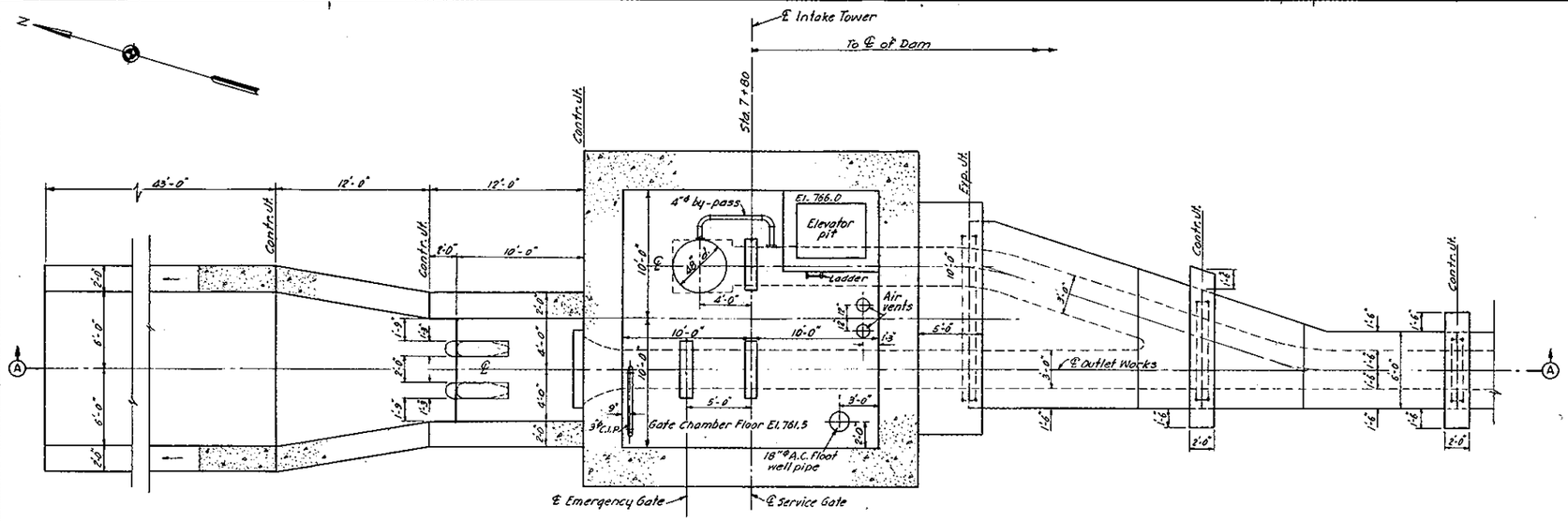
SUBMITTED — CHIEF, SECTION — APPROVAL RECOMMENDED — CHIEF, TECH. ENG. BRANCH — REVIEWED — PROJECT ENGINEER — APPROVAL RECOMMENDED — CHIEF BRANCH

APPROVED — DATE — CHIEF, ENGINEERING DIVISION

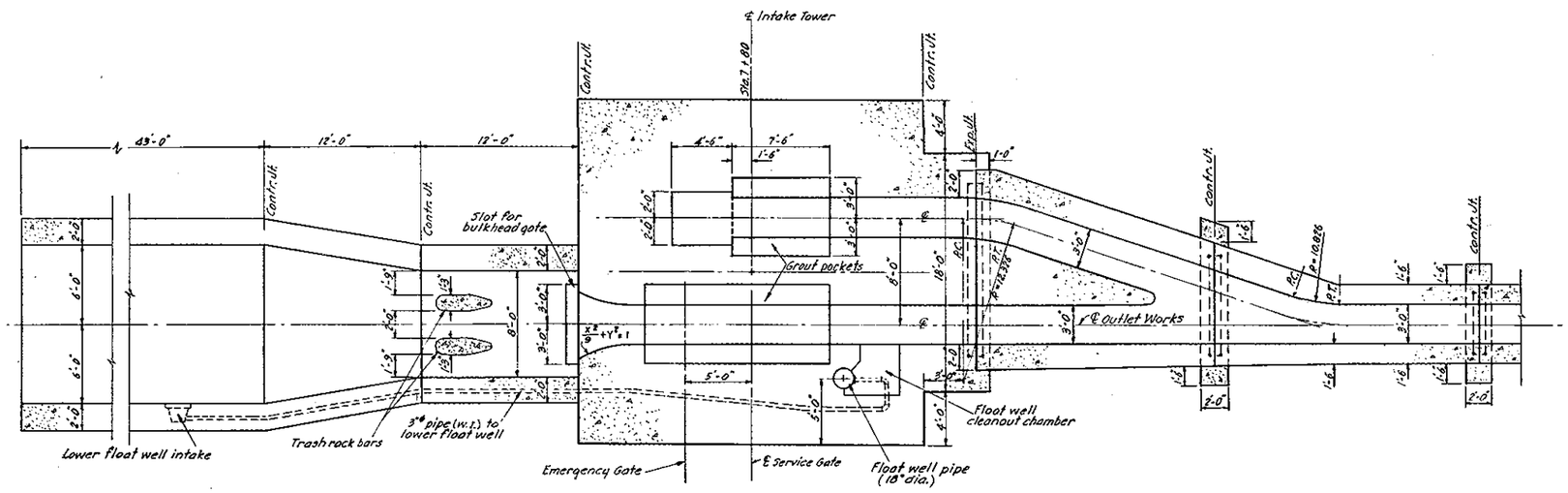
SCALE 1" = 20' | SPEC. NO. | DRAWING NUMBER | SHEET

PLATE 2-5

CORPS OF ENGINEERS — U. S ARMY



PLAN — GATE CHAMBER



SECTION B–B

GRAPHIC SCALES

1/4" = 1'-0"

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

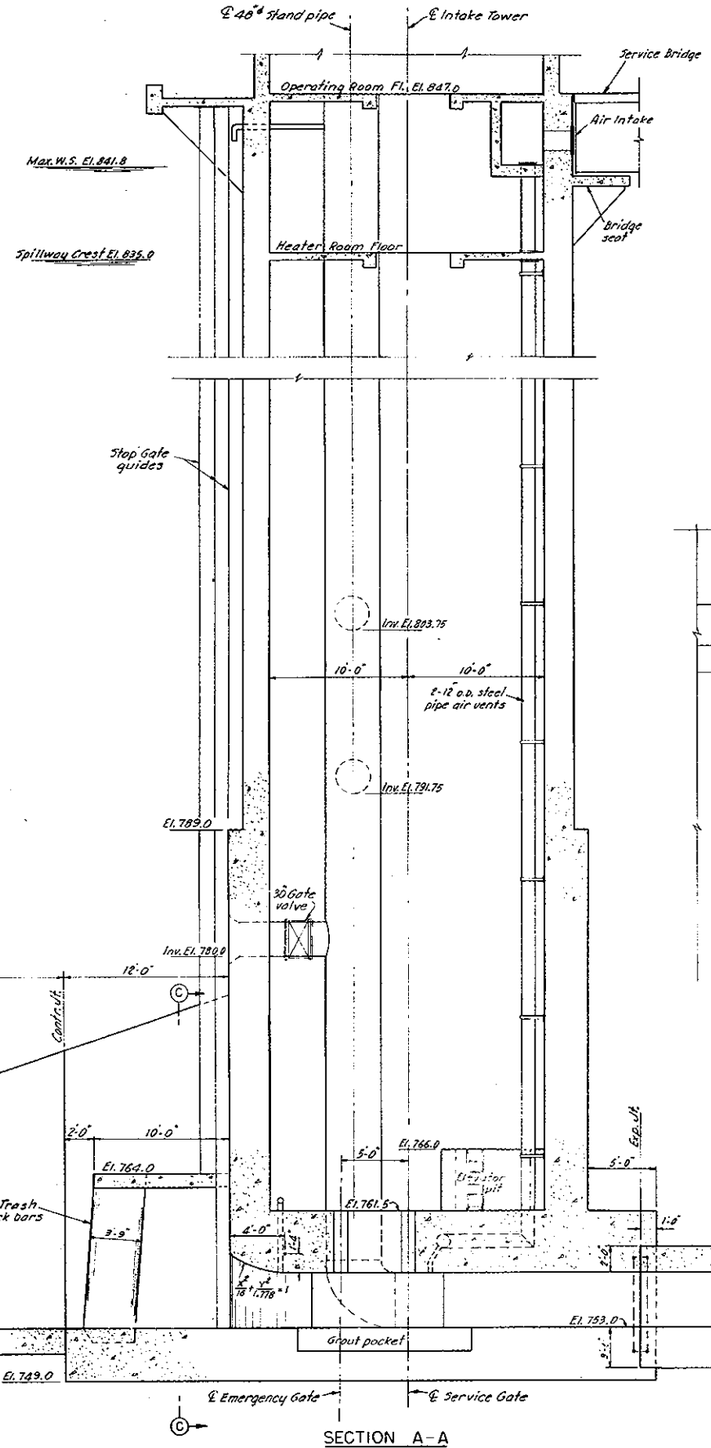
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

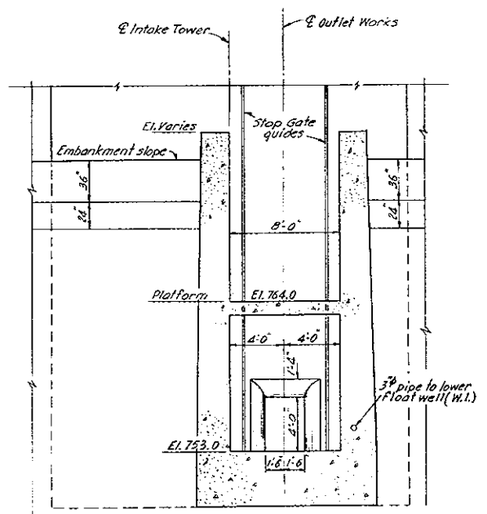
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
OUTLET WORKS
INTAKE TOWER - PLAN & SECTION
PHILLIPS BROOK — MASSACHUSETTS

DES. BY | DR. BY | CK. BY
SUBMITTED
CHIEF, DESIGN
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
RECOMMENDED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF ENGINEERING BRANCH
APPROVED — DATE
CHIEF, ENGINEERING BRANCH
SCALE 1/4"=1'-0" | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 2-6

CORPS OF ENGINEERS A B C D E F G H U. S ARMY





GRAPHIC SCALES

1/4" = 1'-0" 0 4' 8'

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
SUBMITTED:		
CHIEF, SECTION		
APPROVAL RECOMMENDED:		
CHIEF, ENGR. BRANCH		
RECOMMEND:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:		
CHIEF, BRANCH		

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
OUTLET WORKS
INTAKE TOWER - ELEVATION & SECTION
PHILLIPS BROOK MASSACHUSETTS

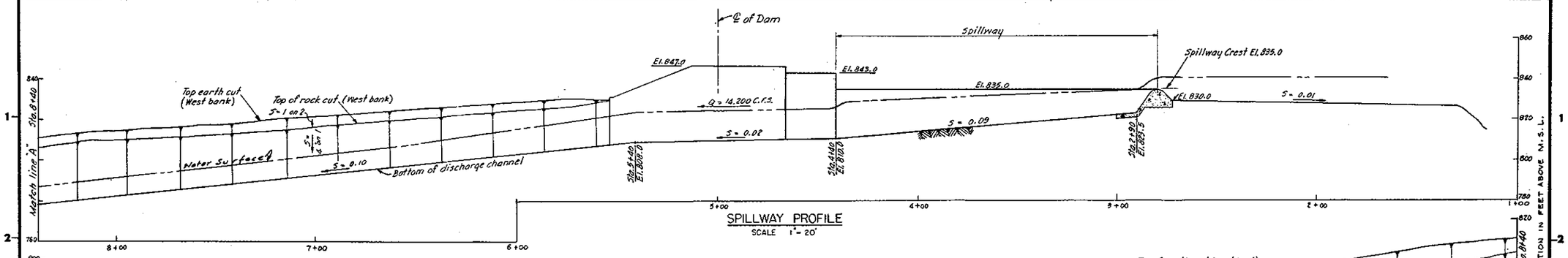
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER

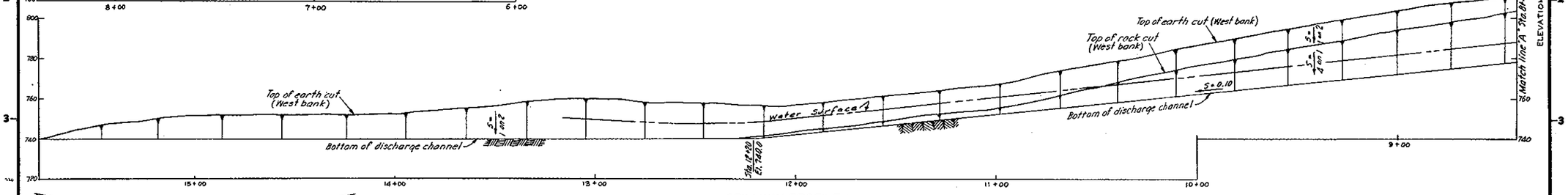
SHEET

PLATE 2-7

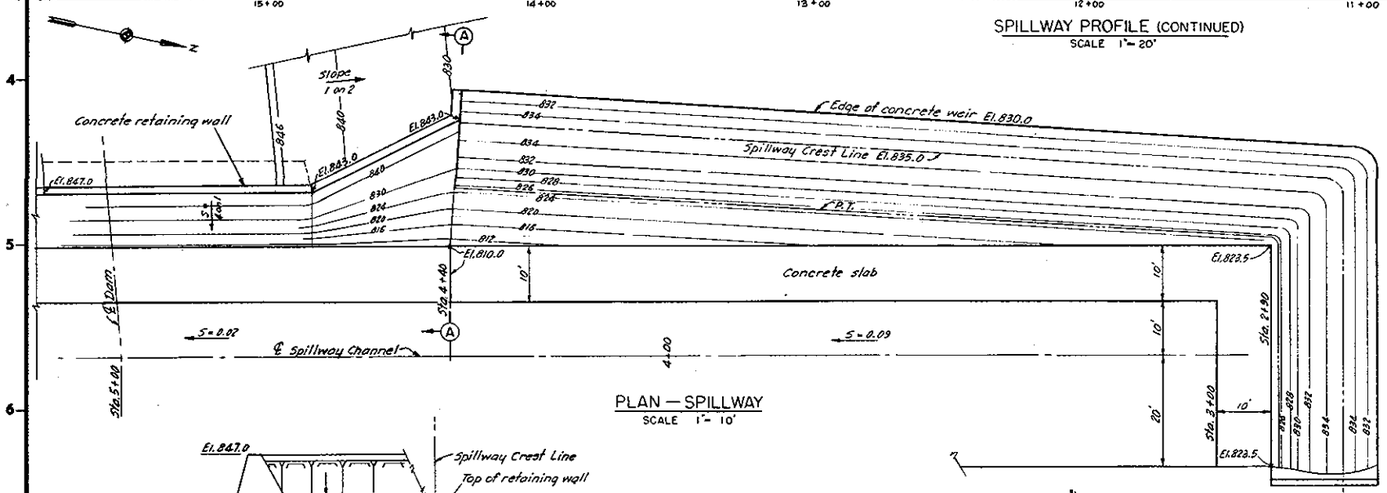
CORPS OF ENGINEERS — U. S ARMY



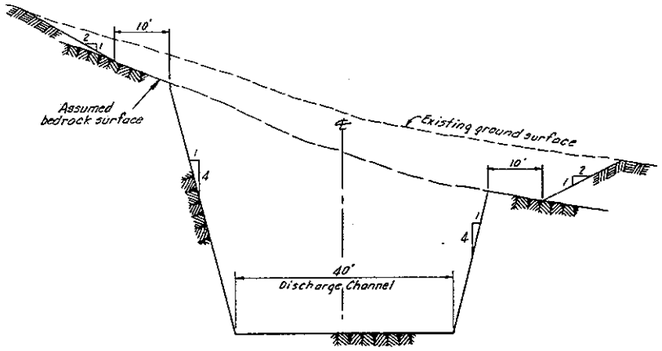
SPILLWAY PROFILE
SCALE 1" = 20'



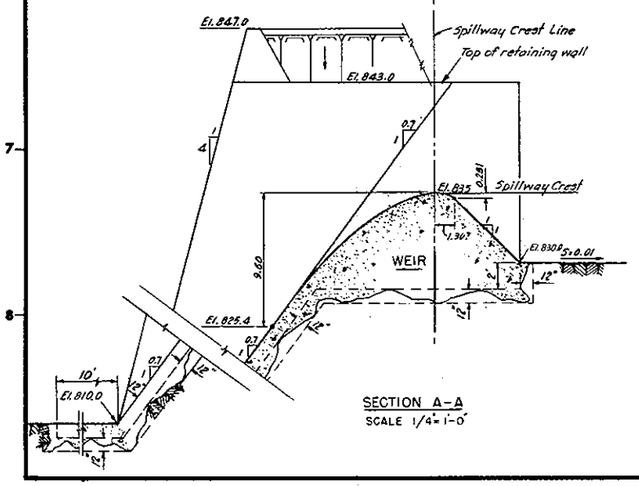
SPILLWAY PROFILE (CONTINUED)
SCALE 1" = 20'



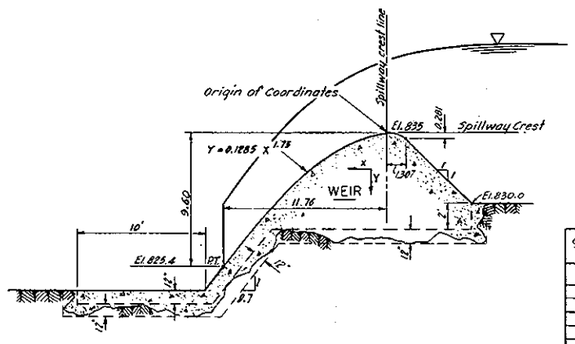
PLAN — SPILLWAY
SCALE 1" = 10'



SECTION STA 7 + 00
SCALE 1" = 10'



SECTION A—A
SCALE 1/4" = 1'-0"



TYPICAL SECTION — SPILLWAY WEIR
SCALE 1/4" = 1'-0"

COORDINATES FOR SPILLWAY WEIR	
X	Y
−1.307	0.281
−1.005	0.157
−0.670	0.0677
−0.134	0.0027
1.0	0.128
3.0	0.879
5.0	2.148
7.0	3.871
10.00	7.225
11.763	9.600

GRAPHIC SCALES
1" = 10' 0 10' 20'
1" = 20' 20' 0 20' 40'
1/4" = 1'-0" 4' 0 4' 8'

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
SPILLWAY
PLAN, PROFILE AND SECTIONS
PHILLIPS BROOK MASSACHUSETTS

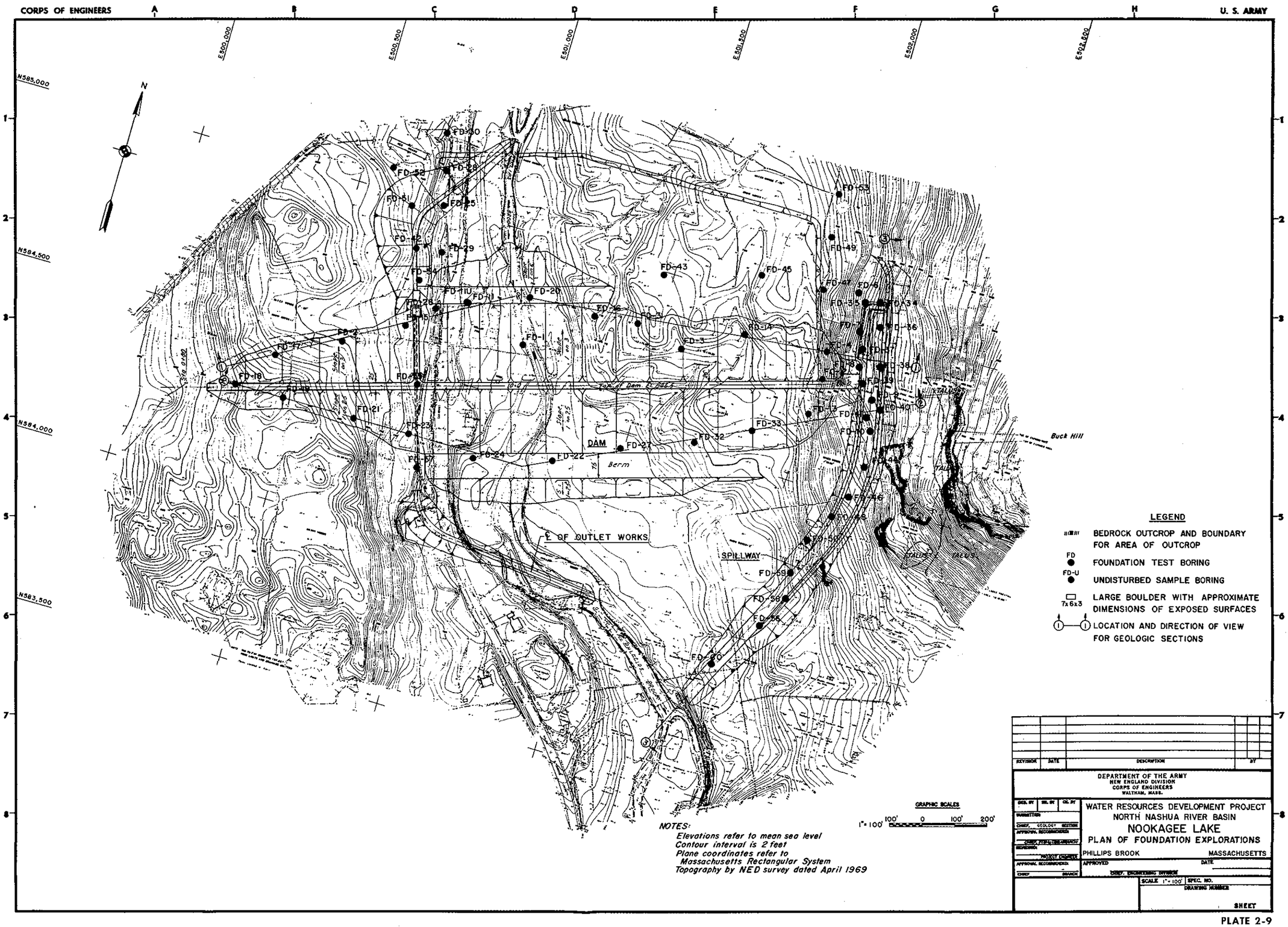
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 2-8

CORPS OF ENGINEERS

U. S. ARMY



LEGEND

- BEDROCK OUTCROP AND BOUNDARY FOR AREA OF OUTCROP
- FD — FOUNDATION TEST BORING
- FD-U — UNDISTURBED SAMPLE BORING
- 7x6x3 — LARGE BOULDER WITH APPROXIMATE DIMENSIONS OF EXPOSED SURFACES
- ① — ① LOCATION AND DIRECTION OF VIEW FOR GEOLOGIC SECTIONS

GRAPHIC SCALES

1" = 100' 100' 0 100' 200'

NOTES:
Elevations refer to mean sea level
Contour interval is 2 feet
Plane coordinates refer to
Massachusetts Rectangular System
Topography by NED survey dated April 1969

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DET. BY | CK. BY

SUBMITTED
CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED
CHIEF, FIELD EXPLORATION BRANCH
RECOMMENDED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF ENGINEERING BRANCH

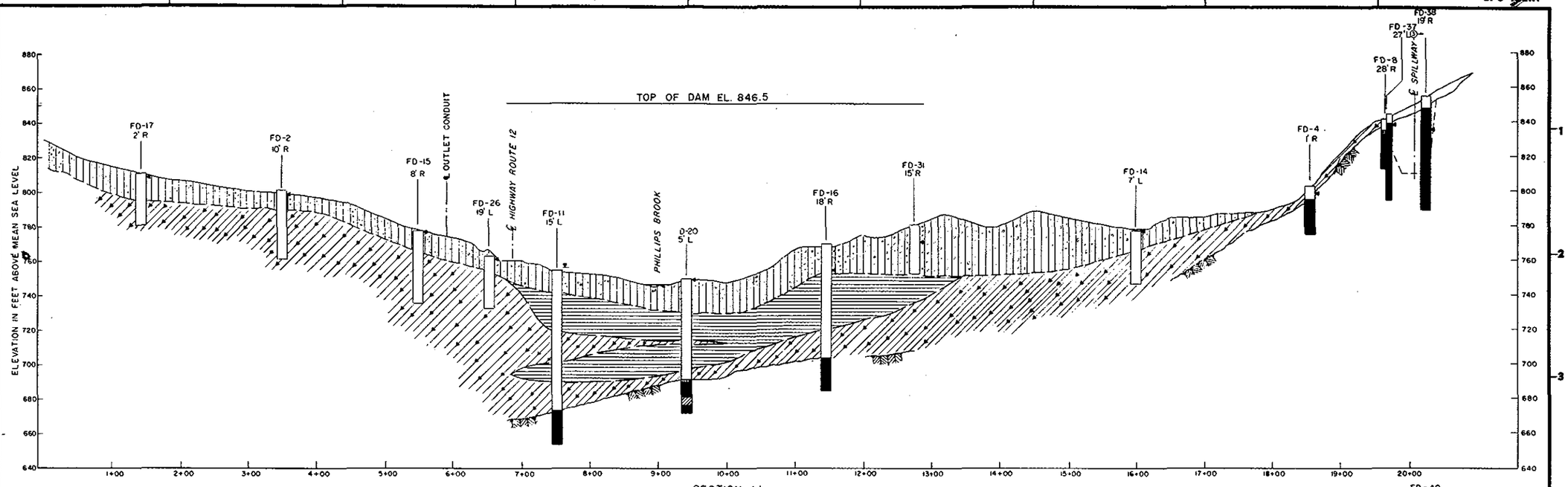
WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
PLAN OF FOUNDATION EXPLORATIONS
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE 1"=100' | SPEC. NO.
DRAWING NUMBER
SHEET

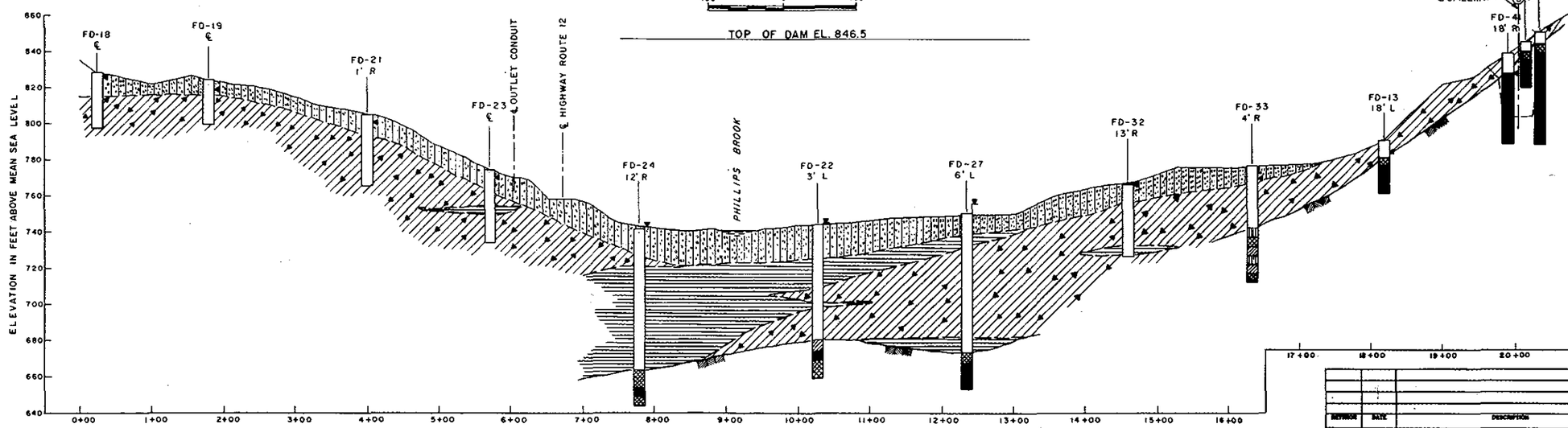
PLATE 2-9

CORPS OF ENGINEERS U. S. ARMY



SECTION 1-1
(LOOKING UPSTREAM)

SCALE IN FEET
100 0 100



SECTION 2-2
(LOOKING UPSTREAM)

SCALE IN FEET
100 0 100

LEGEND

- Assumed bedrock surface
- Variably stratified and lensed silty and/or gravelly SAND and silty and/or sandy GRAVEL with scattered cobbles and boulders.
- Stratified sandy to clayey SILT and silty SAND
- Variable, silty and gravelly SAND and silty, sandy GRAVEL with numerous cobbles and boulders (TILL)

FD Foundation test boring
Maximum artesian head
Subsurface water level during exploration
Rock core recovery
0 - 25%
25 - 50%
50 - 75%
75 - 90%
90 - 100%

NOTE
FOR LOCATION OF SECTIONS SEE PLATE 2-7

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
DAM
GEOLOGIC SECTIONS
PHILLIPS RIVER MASSACHUSETTS

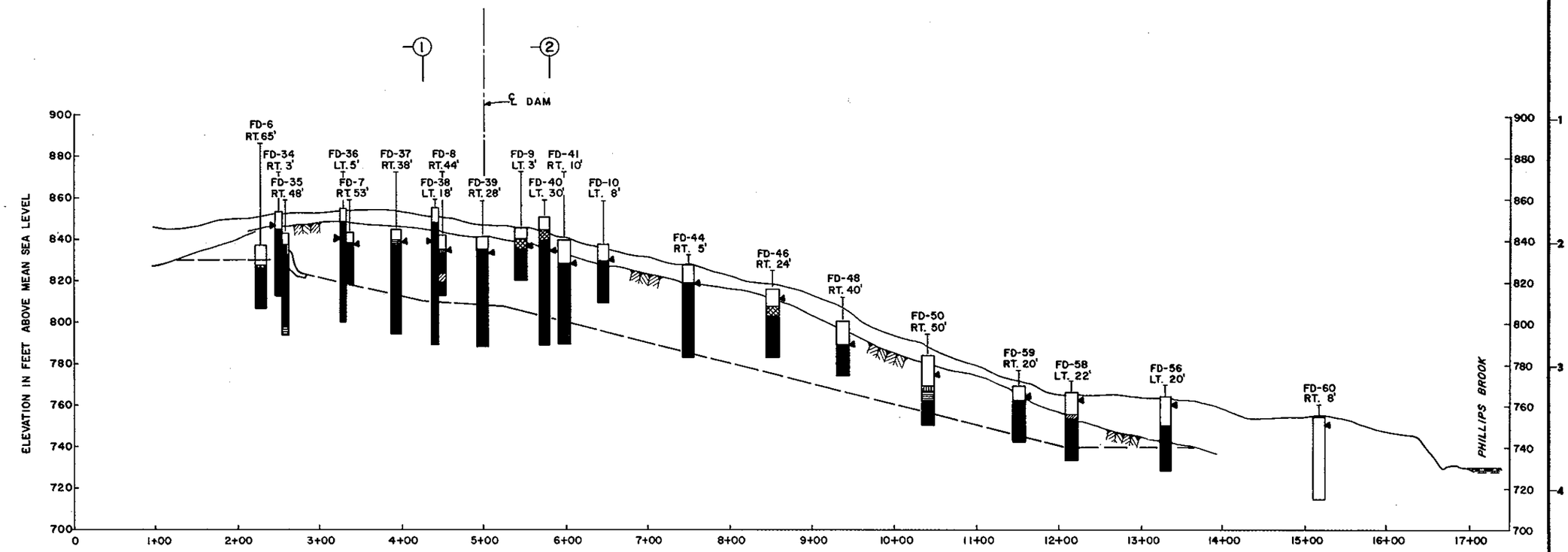
APPROVED DATE

SCALE AS SHOWN SPEC. NO.

SHEET

PLATE 2-10

CORPS OF ENGINEERS — U. S. ARMY



SECTION 3-3 & SPILLWAY

NOTES

FOR LOCATION OF SECTION SEE PLATE 2-7
FOR LEGEND OF GEOLOGIC SECTION SEE PLATE 2-8
SPILLWAY CHANNEL GRADES ARE PRELIMINARY; FINAL GRADES WILL BE SHOWN IN HYDRAULIC ANALYSIS DESIGN MEMO.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, GEOLOGY SECTION
APPROVAL RECOMMENDED:
CHIEF, F & M BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
SPILLWAY
GEOLOGIC SECTION
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO. ENG. 19-016-
DRAWING NUMBER
SHEET

PLATE 2-11

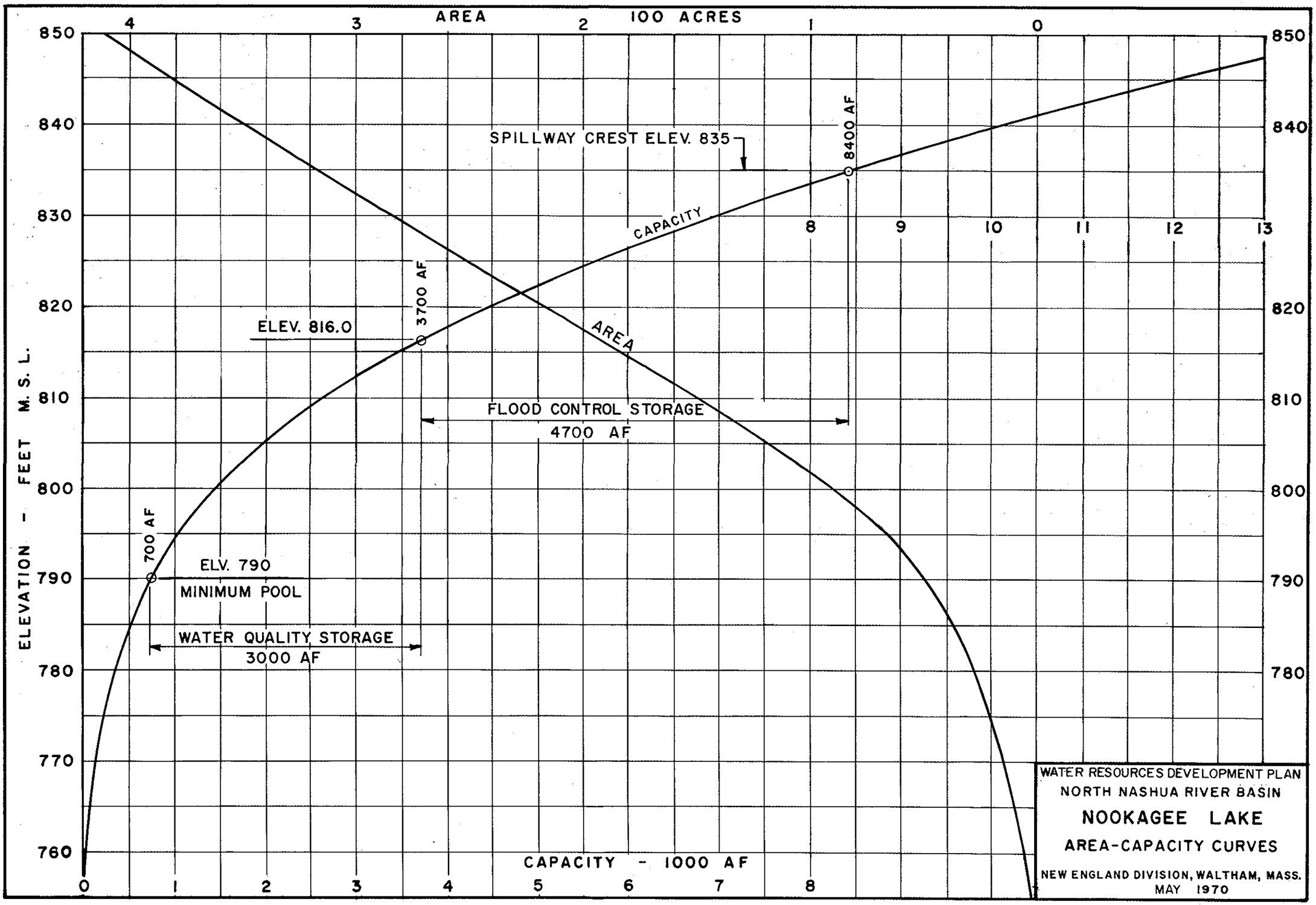
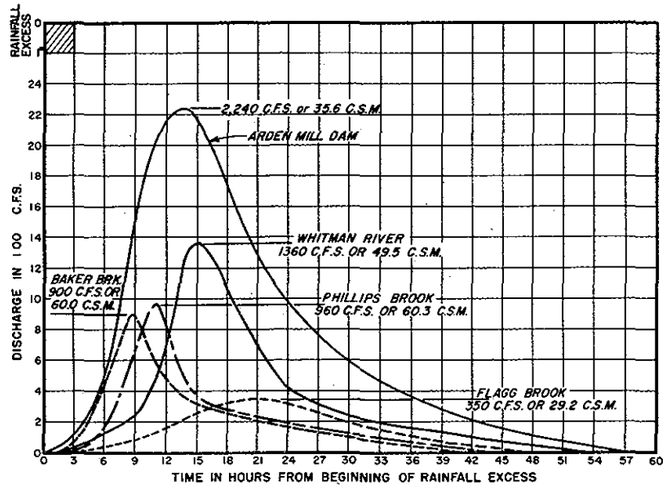
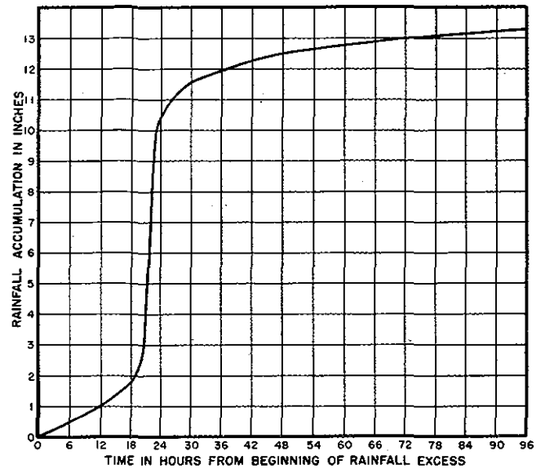

AREA
100 ACRES
4
3
2
1
0
850
840
830
820
810
800
790
780
770
760
M. S. L.
ELEVATION - FEET
SPILLWAY CREST ELEV. 835
8400 AF
CAPACITY
AREA
ELEV. 816.0
3700 AF
FLOOD CONTROL STORAGE
4700 AF
700 AF
ELV. 790
MINIMUM POOL
WATER QUALITY STORAGE
3000 AF
8
9
10
11
12
13
CAPACITY - 1000 AF
0
1
2
3
4
5
6
7
8
WATER RESOURCES DEVELOPMENT PLAN
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
AREA-CAPACITY CURVES
NEW ENGLAND DIVISION, WALTHAM, MASS.
MAY 1970

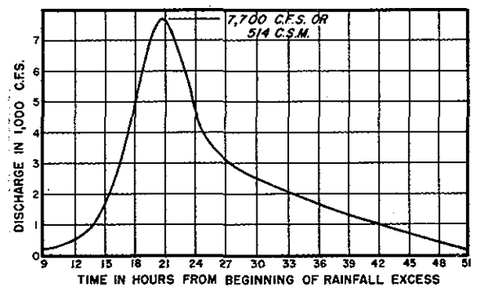
PLATE 2-12



THREE-HOUR UNIT HYDROGRAPHS



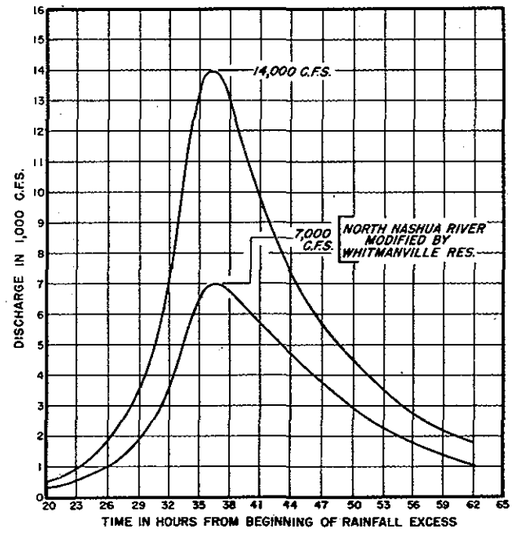
STANDARD PROJECT STORM RAINFALL



BAKER BROOK AT SUMMER STREET

NORTH NASHUA RIVER
AT ARDEN MILL DAM

NORTH NASHUA RIVER
BELOW MOUTH OF PHILLIPS BROOK



NORTH NASHUA RIVER
ABOVE MOUTH OF PHILLIPS BROOK

PROPOSED RESERVOIR SYSTEM

RESERVOIR	DRAINAGE AREA
1.) WHITMANVILLE	17.5 SQ. MI.
2.) NOOKAGEE	11.0 SQ. MI.
3.) PHILLIPS	(NET) 5.0 SQ. MI.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY	CK. BY
R.W.M.	M.S.	R.W.M.

E.F. Story ENGINEER
E.F. Chiesa CHIEF, HYD. & HYD. SECTION
SUBMITTED BY CHIEF, PLANS & RPTS. BRANCH
APPROVED CHIEF ENGINEERING DIV.

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER WATERSHED
STANDARD PROJECT FLOOD
AT
FITCHBURG
NORTH NASHUA RIVER, MASSACHUSETTS
DATE JAN. 1965

TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE AS SHOWN
DRAWING NUMBER
SHEET

PLATE 2-13

CORPS OF ENGINEERS

U. S. ARMY

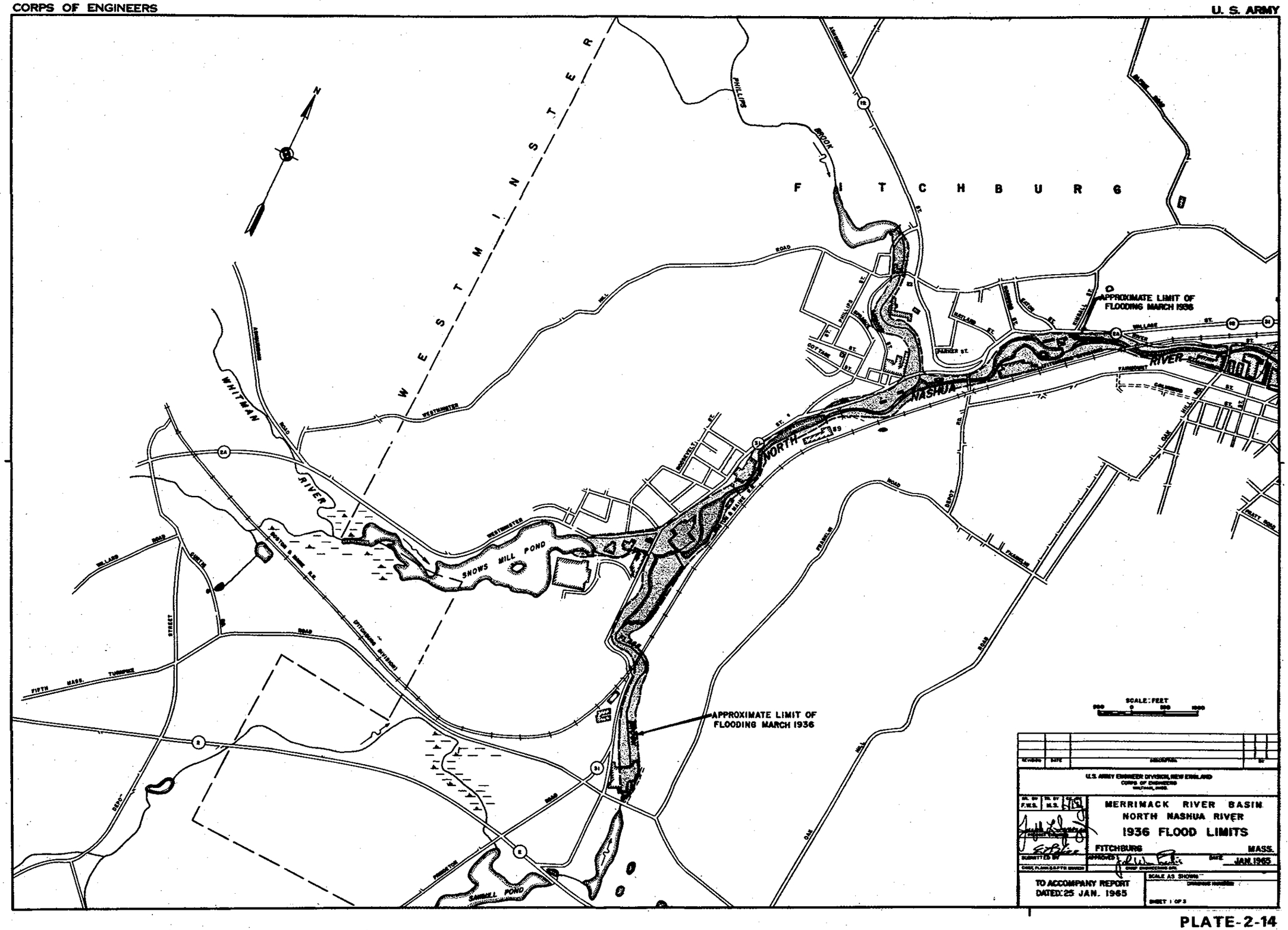


PLATE-2-14

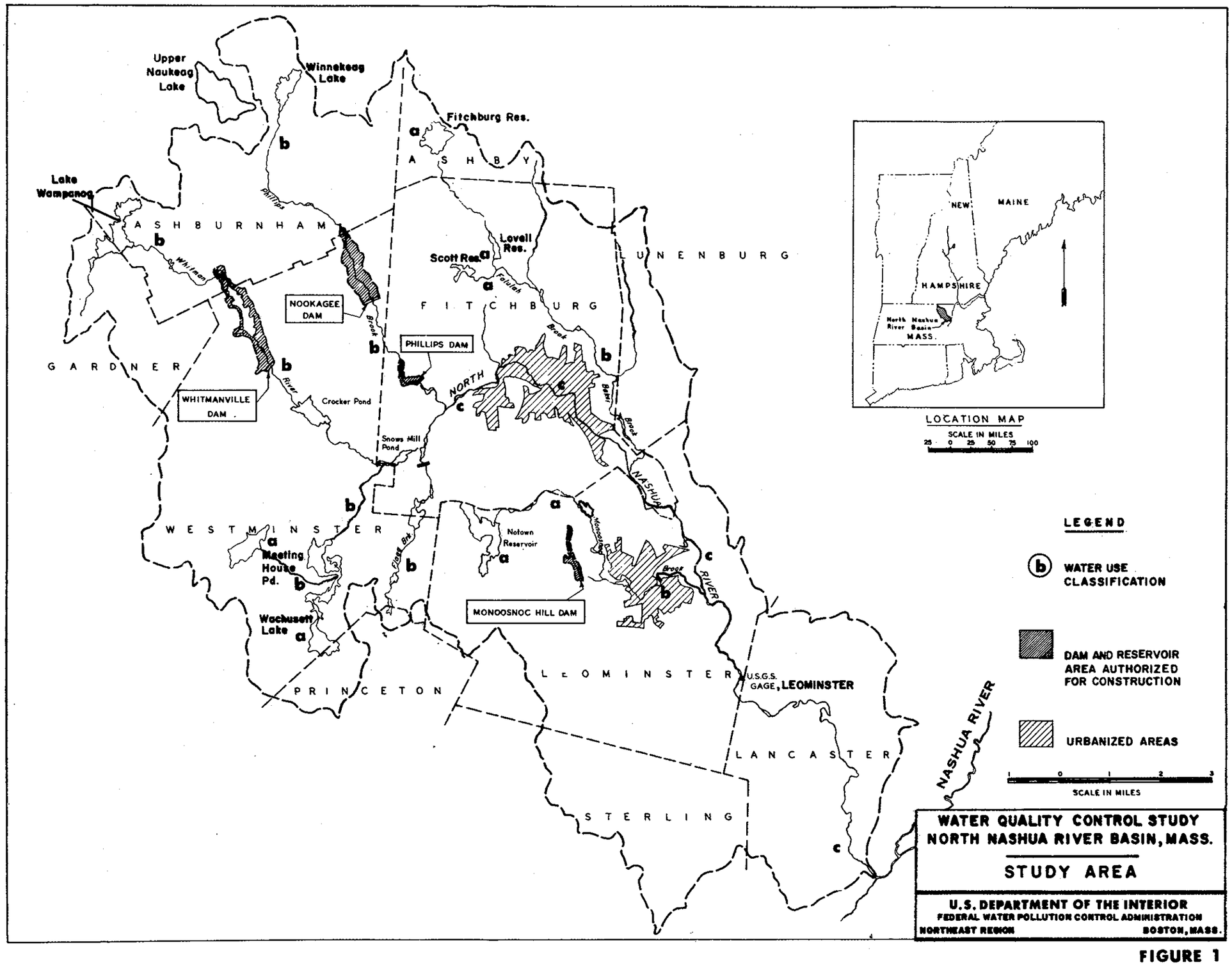
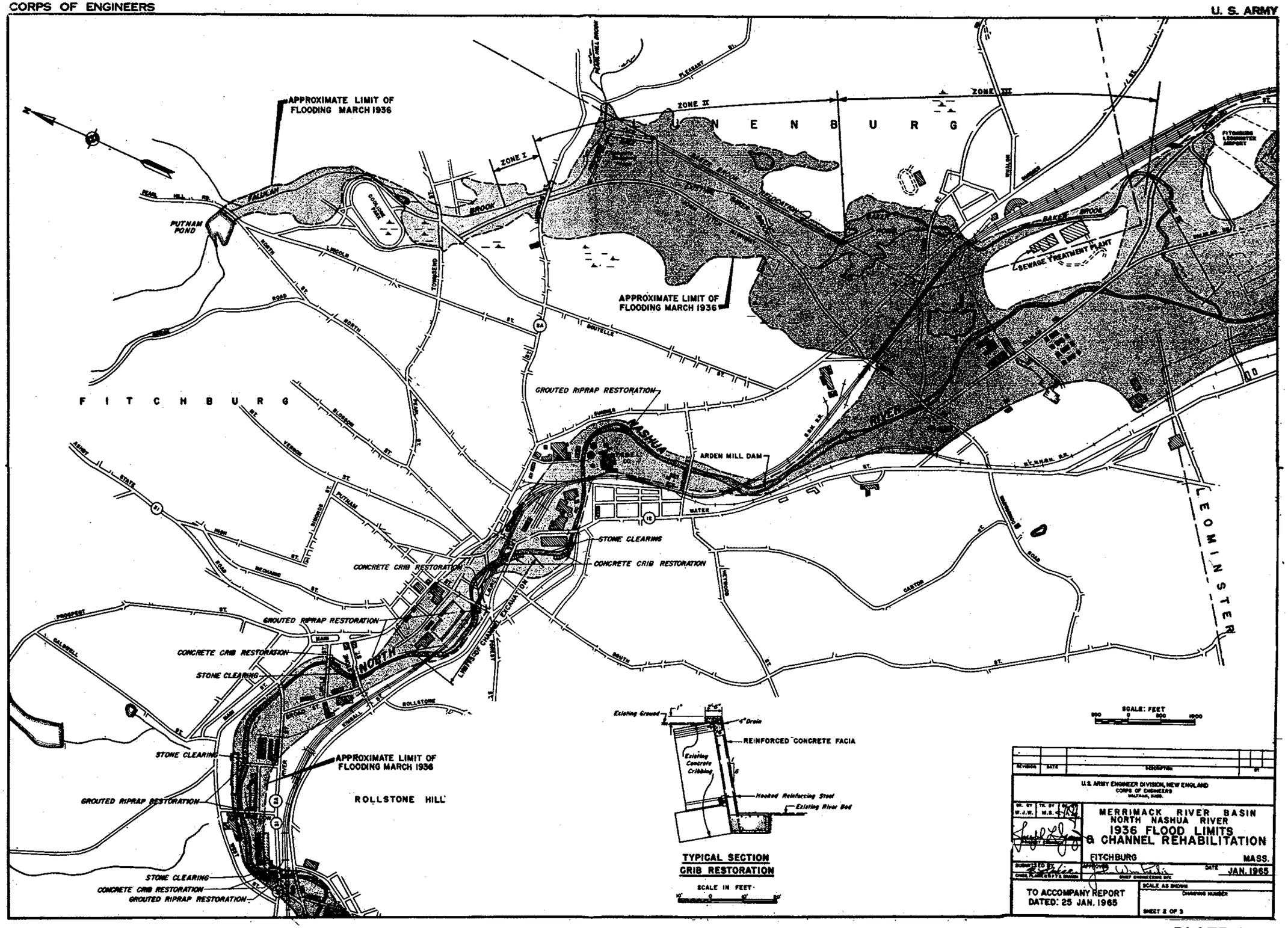

Upper Naukeag Lake
Winnekeag Lake
Fitchburg Res.
Lake Wampanoag
ASHBURNHAM
ASHBY
Phillips Brook
Whitman River
Scott Res.
Lovell Res.
Falulah Brook
LUNENBURG
FITCHBURG
NOOKAGEE DAM
PHILLIPS DAM
GARDNER
WHITMANVILLE DAM
Crocker Pond
North Nashua River
Snows Mill Pond
Baker Brook
NASHUA RIVER
WESTMINSTER
Meeting House Pd.
Wachusett Lake
Flag Brook
Notown Reservoir
Monoosnoc Brook
MONOOSNOC HILL DAM
LEOMINSTER
U.S.G.S. GAGE, LEOMINSTER
PRINCETON
LANCASTER
STERLING
NASHUA RIVER
NEW HAMPSHIRE
MAINE
MASS.
North Nashua River Basin
LOCATION MAP
SCALE IN MILES
25 0 25 50 75 100
LEGEND
WATER USE CLASSIFICATION
DAM AND RESERVOIR AREA AUTHORIZED FOR CONSTRUCTION
URBANIZED AREAS
1 0 1 2 3
SCALE IN MILES
WATER QUALITY CONTROL STUDY
NORTH NASHUA RIVER BASIN, MASS.
STUDY AREA
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
NORTHEAST REGION
BOSTON, MASS.

FIGURE 1

CORPS OF ENGINEERS

U. S. ARMY



REVISED	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY	CH. BY
W.J.W.	M.S.	

MERRIMACK RIVER BASIN
NORTH NASHUA RIVER
1936 FLOOD LIMITS
& CHANNEL REHABILITATION

FITCHBURG MASS.

SUBMITTED BY: CHIEF, PLANS & SPECS BRANCH
APPROVED: CHIEF ENGINEERING DIV.
DATE: JAN. 1965

TO ACCOMPANY REPORT
DATED: 25 JAN. 1965

SCALE AS SHOWN
DRAWING NUMBER
SHEET 2 OF 3

PLATE 2-15

CORPS OF ENGINEERS

U. S. ARMY

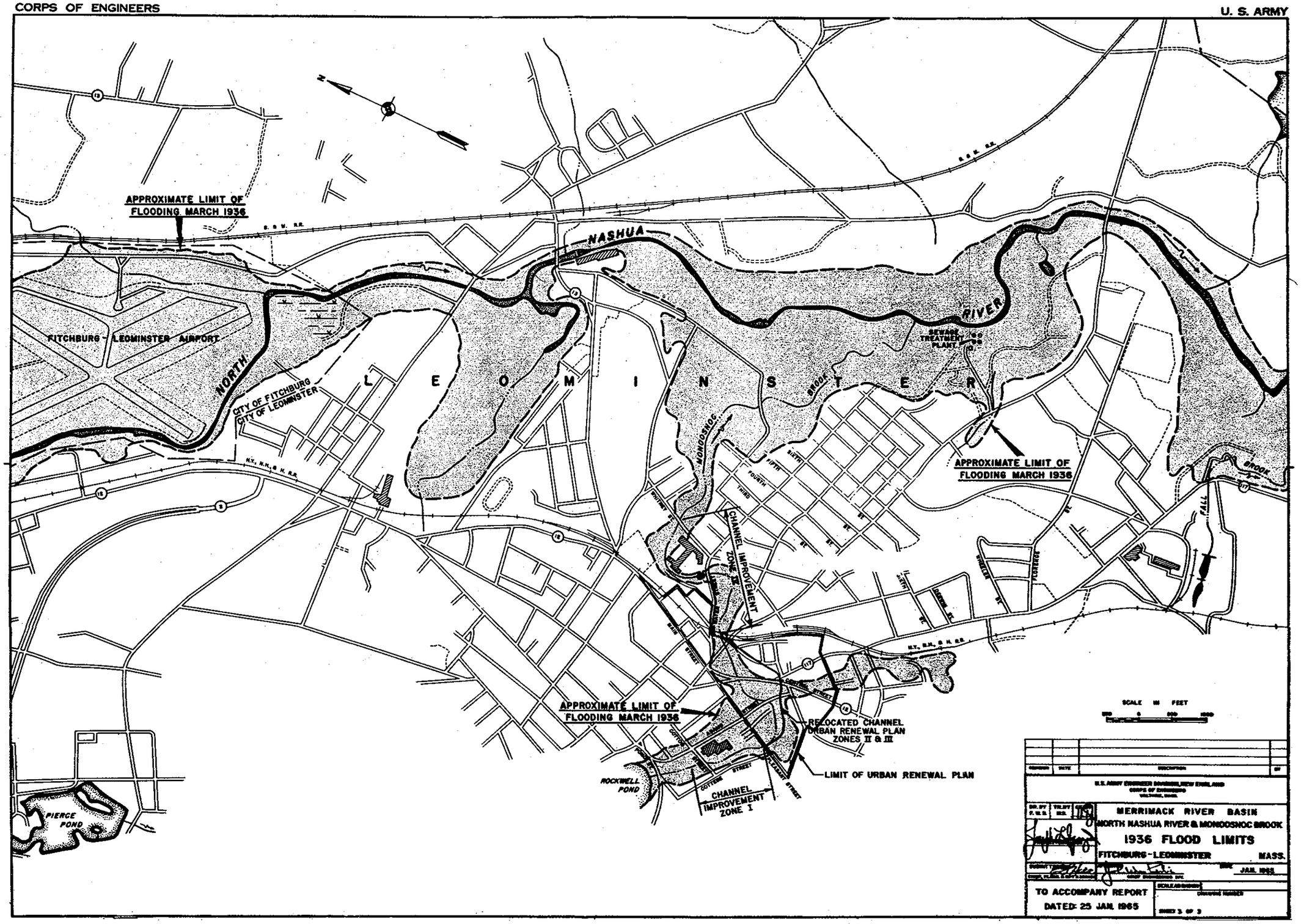


PLATE 2-16

CORPS OF ENGINEERS — U. S. ARMY

A B C D E F G H

N592,000 N590,000 N588,000 N586,000 N584,000 N582,000

E506,000 E504,000 E502,000 E500,000 E498,000

1 2 3 4 5 6 7 8

N

PROPOSED CLIMBING LANE

2 RELOCATION

PROPOSED RELOCATED ROAD

4 CONNECTOR

3 CONNECTOR

1 ABANDON

6 CONNECTOR

5 CONNECTOR

PROPOSED RELOCATED ROAD

TO FITCHBURG

STICKNEY RD.

SHELDON RD.

McINTIRE RD.

FRED SMITH RD.

DEAN HILL RD.

FITCHBURG WESTMIN STER

SPILLWAY ELEV. 835.0

GUIDE TAKING LINE ELEV. 840.0

DAM - TOP ELEV. 846.5

ASHBURNHAM WESTMIN STER

ASHBURNHAM ST. ROUTE 12

TURNAROUND

SPUR ROAD

BORROW AREA

HAUL ROAD

POTATO HILL RD.

BEAN PORRIDGE HILL RD.

MAIN ST. TO ASHBURNHAM

GUIDE TAKING LINE ELEV. 840.0

LOCATION MAP

SCALE IN MILES 5 0 5 10

NEW HAMPSHIRE
MASSACHUSETTS
PROJECT SITE
FITCHBURG
LEOMINSTER
BARRE
WINNIMISSET RESERVOIR
WORCESTER

SAFETY PAYS

GRAPHIC SCALES

1" = 400' 400' 0 400' 800'

LEGEND

NUMBERS IDENTIFY LOCATIONS REFERRED TO IN DESIGN MEMORANDUM.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
HIGHWAY RELOCATIONS
PHILLIPS RIVER MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 2-17

APPENDIX A

REPORT OF THE

BUREAU OF SPORT FISHERIES AND WILDLIFE

FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
U. S. POST OFFICE AND COURTHOUSE
BOSTON, MASSACHUSETTS 02109

1972

Division Engineer
New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

This is our special report on the Nookagee Lake project, as requested by Mr. Leslie's letter of July 2, 1971. The project was authorized by Public Law 89-789, 89th Congress, in accordance with the recommendations of the Chief of Engineers, as contained in Senate Document No. 113, 89th Congress. This report is prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-666 inc.), in cooperation with the Massachusetts Division of Fisheries and Game.

We understand the project's purposes are flood control, water quality, and limited recreation. Storage for water quality will be used to meet the minimum flow requirements set by the Environmental Protection Agency for the North Nashua River.

The dam will be located on Phillips Brook, about four miles northwest of the City of Fitchburg, Massachusetts. It will control an 11.0 square mile area or approximately 70 percent of the 15.9 square mile drainage area of Phillips Brook, a tributary of the North Nashua River.

The reservoir site is a mix of forest, cropland, and pasture and is sparsely populated. The area is roughly bisected by Phillips Brook and Route 12, a secondary highway. Fish and wildlife oriented recreation is limited in the North Nashua River Basin because paper companies own a major portion of the land and have prevented public use. The Whitmanville Dam authorized for construction is located two miles west of the Nookagee Dam.

PROJECT DESCRIPTION

The dam will be of earth-fill construction, 2,150 feet long by 106 feet high. The reservoir at spillway crest elevation 835 1/ will have

1/ Elevations are in feet above mean sea level.

a surface area of about 318 acres. Total storage capacity will be 8,400 acre-feet; equal to 14.6 inches of runoff. The total storage includes allocation of 4,700 acre-feet for flood control, 3,000 acre-feet for water quality, and 700 acre-feet for a minimum pool.

We understand the project will be operated in essentially the following manner: by the end of spring runoff in April, the reservoir will be filled to elevation 816 (190 acres). During the months of July and August, for the average year, releases will be made for water quality, bringing the pool down 14 feet to elevation 802 (100 acres) by Labor Day. During September and October, the pool will be held at elevation 802, with water quality releases coming from the Whitmanville Dam which is located two miles to the west. Drawdowns based on the probability of a dry season every five years could be 18 feet and in one year out of ten, 25 feet. Between the period November through April, the water quality pool will be refilled as soon as possible while maintaining mutually agreed upon downstream requirements. Table 1 lists the elevation, drawdown, area, storage and depth of the reservoir during the period April to October. One year in two, flood storage would be six feet above the April pool elevation of 816. These storages can be released in one to two days. It is expected that with releases for water quality during July and August, flows in Phillips Brook downstream from the Nookagee Dam would be between 17 to 20 cfs. Figure 1 depicts the various pool elevations at different times of the year.

Table 1. Physical Characteristics, Nookagee Reservoir

Date	Elevation	Drawdown (Ft.)	Area (Ac.)	Volume (Ac.-Ft.)	Max. Depth (Ft.)
April 30	816	0	190	3,700	73
May 31	816	0	190	3,700	73
June 30	816	0	190	3,700	73
July 31	810	6	150	2,650	67
August 31	802	14	100	1,650	59
September 30	802	14	100	1,650	59
October 31	802	14	100	1,650	59
Every 5th Year (Minimum Pool)	798	18	82	1,250	55
Every 10th Year (Minimum Pool)	791	25	50	800	48

Fish and Wildlife Resources

The effects of project development on fish and wildlife resources were determined by comparing the estimated utilization of these resources

under "without-the-project" conditions with those estimated with the project in operation. Utilization is expressed as the average annual fisherman- or hunter-days over a 100-year life of the project and is a reflection of the productive capability of affected habitat types. The dollar value of benefits given are net recreational values. They are based on "Evaluation Standards for Primary Outdoor Recreation Benefits" adopted by the President's Ad Hoc Water Resource Council, June 4, 1964[2/].

Fishery Resources - Without-the-Project

Phillips Brook in the Towns of Ashburnham, Fitchburg, and Westminster is stocked annually on a "put-and-take" basis with about 3,000 brook trout and 350 brown trout. The brown trout and 1,500 of the brook trout represent in-season stocking. The two-mile length of stream to be inundated by the project represents one of the best trout streams in the area. The existing annual fishing pressure for the two-mile segment is approximately 800 man-days. The average annual fishing pressure expected for this segment over the next 100 years is estimated to be 2,000 fisherman-days.

Due to the low water levels during the summer, there is insignificant utilization of the two-mile segment of Phillips Brook downstream of the dam.

Fishery Resources - With-the-Project

Construction of the Nookagee Dam will inundate two miles of trout stream and will create a minimum pool of 100 acres during an average year. With the maximum depth being 59 feet, it is expected that a cold- and warm-water fishery will be established. Largemouth bass, yellow perch, pickerel, and bullhead will provide the bulk of the warm-water fishing, and brook trout will provide cold-water fishing opportunity.

If public access and boat-launching facilities are provided, it is estimated that the average annual utilization of the reservoir over the life of the project will be 11,300 fisherman-days, for a net recreational value of $34,000.

With a minimum July-August flow of 17 cfs. occurring in the two-mile segment downstream from the dam, the trout season will be extended by as much as two months, and fishing will be improved to the extent of providing an estimated 2,000 fisherman-days opportunity, for a total recreational value of $8,000. These benefits will occur only if public access is assured.

2/ See "Supplement #1 - Evaluation Standards for Primary Outdoor Recreation Benefits", to Senate Document No. 97, 87th Congress, 2nd Session.

The net average annual fishery benefit for the project will be 11,300 fisherman-days, having a recreational benefit of $34,000. Table 2 lists the average annual fishery utilization and values.

Table 2. Average Annual Fishery Utilization and Values

Area Evaluated	Without-the Project		With-the-Project		Difference	
	Fisherman-Days	Value $	Fisherman-Days	Value $	Fisherman-Days	Value $
Reservoir Fishery	0	0	11,300	$34,000	11,300	$34,000
Stream Fishery (Inundated)	2,000	$8,000	0	0	-2,000	-$ 8,000
Stream Fishery (Downstream from dam)	0	0	2,000	$ 8,000	2,000	$ 8,000
TOTALS	2,000	$8,000	13,300	$42,000	11,300	$34,000

Wildlife Resources - Without-the-Project

The 318-acre area within the maximum flow line of the reservoir provides fair to good habitat for wildlife species such as white-tailed deer, ruffed grouse, woodcock, snowshoe hare, gray squirrel and ring-necked pheasant, the latter species being stocked. This area will provide an average annual utilization of 100 hunter-days over the life of the project. In addition, various non-game animals and birds are present in the area, and afford some opportunity for nature study and bird-watching. An estimated 50 man-days of nature study and bird-watching could be provided over the life of the project.

Wildlife Resources - With-the-Project

Construction of the Nookagee Dam will eliminate about 190 acres of wildlife habitat. In addition, the productive capability of lands lying within the maximum flow line will be reduced as a result of seasonal flooding and general recreational use.

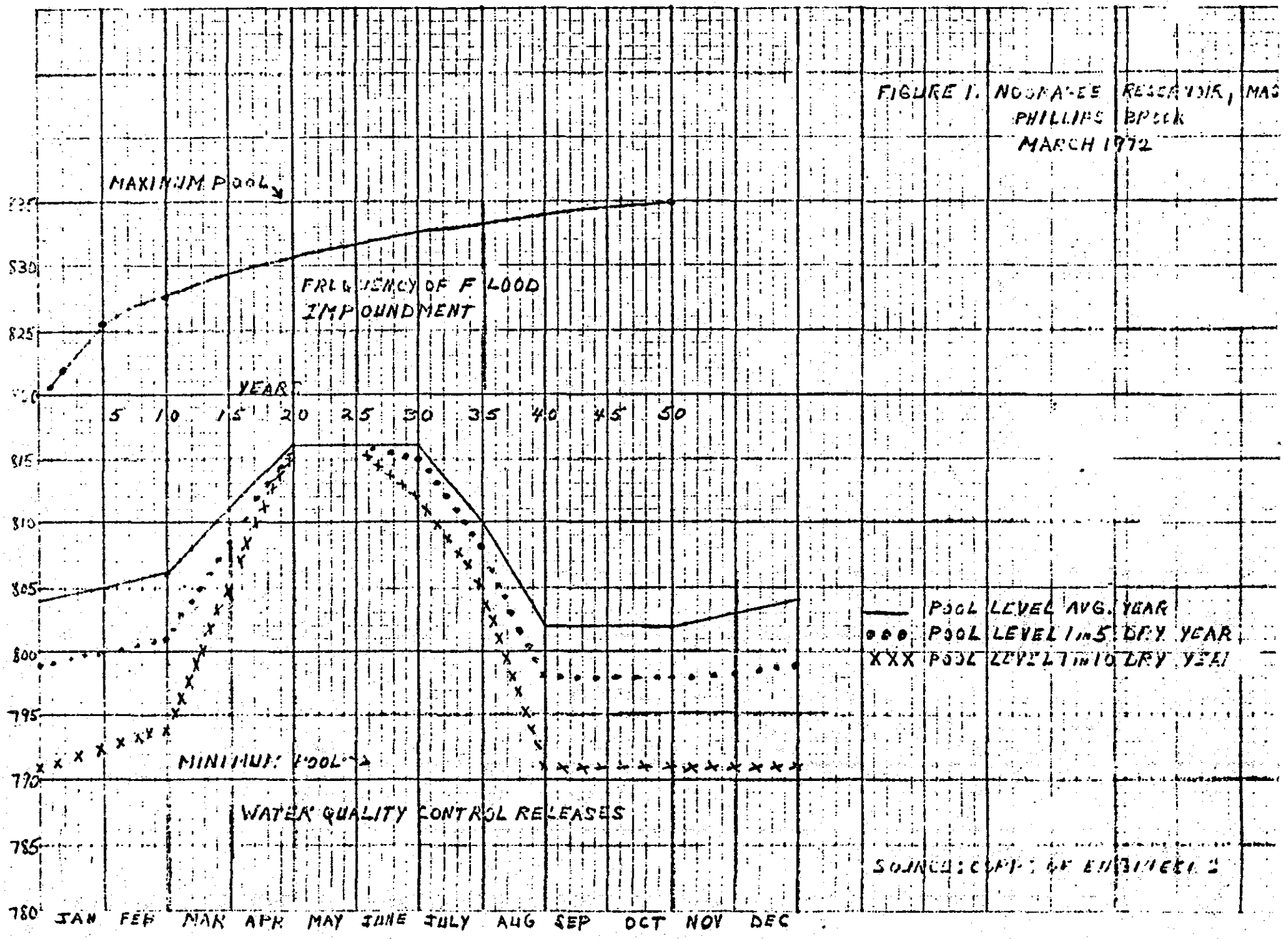


FIGURE 1. NOORA-EE RESERVOIR, MAS
PHILLIPS BROOK
MARCH 1972
MAXIMUM POOL
FREQUENCY OF FLOOD IMPOUNDMENT
YEAR
5 10 15 20 25 30 35 40 45 50
835
830
825
820
815
810
805
800
795
790
785
780
MINIMUM POOL
WATER QUALITY CONTROL RELEASES
JAN FEB MAR APR MAY JUNE JULY AUG SEP OCT NOV DEC
POOL LEVEL AVG. YEAR
POOL LEVEL 1 in 5 DRY YEAR
XXX POOL LEVEL 1 in 10 DRY YEAR
SOURCE: CORPS OF ENGINEERS

During spring, in an average year, the reservoir will have approximately 45 acres of water four feet deep, or less, at the upper end of the reservoir. This will provide a "fair" to "good" quality habitat for waterf owl nesting, as well as opportunities for nature study and bird-watching. This will result in an annual recreational value of approximately $200.00. Available hydrological data indicate that spring flood storages above elevation 816 would normally occur in March and early April, before the waterfowl nesting period.

Discussion

The public must have guaranteed access to the full length of the downstream segment in order to realize maximum benefits. Posting of the stream is not a problem at present; however, steps should be taken by the Corps of Engineers to guarantee future access to the stream banks, through land acquisition or easements. Trout fishing benefits from flow augmentation cannot be assured without public access. Acquisition in fee of a strip 50-100 feet wide on alternate banks of the two-mile improved reach is preferred, but easement would be less costly and satisfactory from a utilization viewpoint.

The increase in fisherman-days from a present 800 to 2,000 under "without-the-project" conditions is based on several assumptions. Every five years the Department of the Interior publishes a "National Survey of Fishing and Hunting". Since 1955, the general trend has been toward an increased number of fishermen, both in number and percentages, although the latest survey in 1970 showed a decline. We are assuming that as the population rises the number of fishermen will increase, and will place a heavier demand on streams and lakes. Another assumption is that at some time in the future, the State will take steps to guarantee public access to the 2-mile length of Phillips Brook to be inundated by the project. Phillips Brook provides some of the best trout fishing in the area, and it is reasonable to assume the State will eventually acquire at least fishing rights to portions of the stream.

In order to provide optimum water temperatures and dissolved oxygen (DO) levels for trout survival, and to provide opportunity for management of pool water quality, multiple-gated outlets should be provided at elevations 750,770 and 790 to provide the option of water releases from several elevations.

To prevent undesirable effects of vast expanses of exposed mud flats, the area between elevations 816 and 802, with the exception of the potential

waterfowl habitat at the upstream end of the reservoir, should be stripped down to mineral soil. This would provide desirable spawning areas for various fish species and provide an aesthetically pleasing area.

To provide fisherman access to the reservoir at various pool levels during the summer months, portions of Dean Hill Road, Bean Hill Road, and Smith Road, between elevations 816 and 791, should contain boat-launching ramps and parking facilities for 10 - 15 cars each.

Although releases for water quality will stop after Labor Day, a maintenance flow of about 2 cfs. should be maintained during September and October.

The loss of upland and forest game habitat through inundation will be mitigated by the creation of shallow water areas which would be utilized by waterfowl. An opportunity for bird-watching and nature study would also be provided. To provide nesting sites for wood ducks and other birds, timber in this shallow water area should not be cleared.

Recommendations

It is recommended that:

1. Public access to the two-mile segment below the dam be guaranteed in the future by land acquisition and/or easements.

2. Multiple-level intakes be included in the outlet works and designed to take water from approximate elevations of 750, 770, and 790.

3. Pool margins exposed by seasonal drawdown, with the exception of the upper end of the reservoir, be stripped between elevations 816 and 802 of all organic material down to mineral soil.

4. Portions of Dean Hill Road, Bean Hill Road, and Smith Road, between elevations 816 and 791, be made into boat-launching ramps to provide fishermen access at various pool levels and parking facilities for 10-15 cars be provided at each ramp.

5. A minimum flow equal to about 2 cfs. be maintained during the months of September and October.

6. Timber in the shallow water area at the upper end of the reservoir not be cleared.

7. Your agency coordinate with the Massachusetts Division of Fisheries and Game concerning fishery management of the reservoir and downstream areas.

Sincerely yours,

Richard E. Griffith

Regional Director

APPENDIX B

RECREATION RESOURCES

NOOKAGEE LAKE

APPENDIX B

RECREATION RESOURCES

TABLE OF CONTENTS

TABLE OF CONTENTS (Con't)

I. INTRODUCTION

a. Authority. - Nookagee Lake was authorized along with Whitmanville Lake by the Flood Control Act approved 7 November 1966, Public Law 89-789, 89th Congress, as part of the North Nashua River Plan.

The original project purposes of Nookagee Lake were flood control, industrial water supply and recreation. However, in 1969, support for the water supply aspect was withdrawn by local interests and subsequently water quality control was added as a project purpose (see text of GDM). The recommended changes to the project purposes were submitted to the Office of Chief of Engineers on 12 February 1971 and approved on 28 May 1971. As a result, the new project purposes of Nookagee Lake are flood control, water quality control, and limited recreation.

b. Purpose. - This appendix appraises the environmental and recreational resources of Nookagee Lake and estimates the magnitude and growth of public use to be accommodated by the minimum required development while preserving the environmental resources of the project. The amount and cost of the limited recreation facilities, and the fish and wildlife resources are also evaluated and discussed.

c. Scope. - This appendix presents a preliminary plan to serve as a guide for development and administration of Nookagee Lake for public use purposes. The plan includes a description of the project, proposals for public use and access areas, factors influencing public use development, land requirements and preliminary cost estimates for public use facilities.

II. DESCRIPTION OF PROJECT AREA

a. Location. - Nookagee Lake is located on Phillips Brook in the Towns of Westminster and Ashburnham, Massachusetts. Phillips Brook has its source in Winnekeag Lake in the Town of Ashburnham and flows in a generally southward direction for eight miles to its confluence with the North Nashua River. The dam site is about 3.1 miles above the confluence with the North Nashua and the lake extends upstream about 1.4 miles. The dam controls a drainage area of 10.8 square miles. The project site is about 4 miles north of Westminster, 3.6 miles northwest of Fitchburg and 7 miles east of Gardner, Massachusetts.

b. Climate. - The mean annual temperature in the project area is about 48°F with temperature extremes ranging from slightly over 100°F to around -20°F. The average annual precipitation is about 42 inches at Fitchburg and is distributed quite uniformly throughout the year. The annual snowfall averages about 63 inches. The climate is variable as the North Nashua River watershed lies in the path of the prevailing "westerlies" which produce frequent weather changes.

c. Topography. - The project is located in the central upland of Massachusetts, a region of low to moderate relief underlain by crystalline rocks. Although considerably modified by glaciation, the topography is fairly subdued and regular. Long, broadcrested ridges rise in fairly smooth but generally steep slopes above wide valleys which are constricted locally by extensive glacial outwash and till. The till forms a generally thin blanket on the hills and ridges and thick deposits in the valleys. Overlying the till in the valleys are outwash features consisting of rough, irregular, knobby terraces along the valley sides and flat plains in the valley bottoms.

The project site is a mix of forest, cropland and pasture and is rural in character. Mixed hardwoods, white pine and red oak predominate with little wetland within the project area.

d. Ecological Resources. - Fair to good habitat exists within the project area for wildlife species such as white-tailed deer, ruffed grouse, woodcock, snowshoe hare, gray squirrel and ring-necked pheasant, the latter being stocked. A variety of non-game animals and birds are also present in the area.

Phillips Brook is stocked annually with brook and brown trout and is one of the best trout streams in the region. There are many pools and riffles in the brook and considerable tree cover which helps maintain cool water temperatures. Water quality is excellent and good access within the project area attributes to angler use of this resource.

e. Accessibility. - Nookagee Lake is readily accessible to more than 840,000 Massachusetts residents and 140,000 New Hampshire residents who live within about one hour's drive (40 miles) of the project. Massachusetts Route 12 passes through the project area while Route 2, a limited access divided highway, is the major road west from Metropolitan Boston and east from Interstate Route 91. Several other state highways and secondary roads also serve the project area.

f. Environmental Resources. - Nookagee Lake lies in a typical New England rural setting characterized by rolling hills, woods, flowing water and sparse population. There is little urbanization in the immediate area and the availability of project lands and water for public use will be a significant asset to the region. In addition to the scenic aspects of the area there is a good fishery, unspoiled woodland and abundant wildlife.

g. Hydrological Considerations. - The plan of operation for Nookagee Lake consists of filling the reservoir to elevation 816 feet above mean sea level by the end of the spring snowmelt season in March or April. In an average year the reservoir will be drawn down during the months of July and August to elevation 802 for the purpose of improving the water quality downstream by augmenting the flow in Phillips Brook. During September and October the water quality releases will be terminated at Nookagee and the downstream needs will be met by the water quality releases from nearby Whitmanville Lake. The drawdown at Nookagee based on the probability of a

dry season every five years could be 18 feet, to elevation 798, and in one year out of 10 the drawdown could be 25 feet, to elevation 791. From Labor Day to April the pool will be refilled as rapidly as possible while maintaining minimum flow in the stream or in case of flood operations drawn down to elevation 816 by the end of April, as soon as possible.

h. Water Quality. - There is a serious pollution problem in the North Nashua River from the mouth of the Whitman River in Fitchburg to the confluence of the North and South Branches of the Nashua River in Lancaster. Industrial and domestic discharges far exceed the assimilative capacity of the stream. As a result the water quality is poor, and obnoxious and nuisance conditions exist. The tributary flows upstream of the waste discharges are generally of excellent quality, however, and augmentation to improve water quality downstream would be of major economic significance to the entire region.

Future waste loadings downstream of Nookagee Lake will be reduced by a higher degree of treatment, but it can eventually be expected that treated residual waste loadings will increase with time due to industrial and population growth. Low flow augmentation from Nookagee will help maintain desired BOD and DO levels, provide dilution for non-degradable pollutants, increase stream velocities to inhibit obnoxious aquatic growth, create higher water levels for improved aesthetic and recreation enjoyment, and have a stabilizing influence for all downstream reaches regardless of loading conditions.

III. PROJECT DATA

The following table illustrates the pertinent elevations, areas and capacities of the various pools to be held behind Nookagee Dam.

	Elevations (Ft.,msl)	Area (Acres)	Capacity (Acre Feet)	Inches on Drainage Area
Conservation Pool	790.0	50	700	1.2
Water Quality Pool	816.0	190	3000	5.2
Flood Control Pool	835.0	316	4700	8.2
Spillway Crest	835.0	316	8400	14.6
Maximum Surcharge	841.7			

The limited recreation pool will fluctuate between elevation 816.0 and elevation 790.0.

The average depth of Nookagee Lake at elevation 816.0 will be about 30 feet. The water surface will average about 1000 feet across and 7000 feet in length with a shoreline of about 4 miles. The average end of month elevations and areas of the recreation pool from April through October are

shown in the following table:

Month	Elevation	Area
April	816	190
May	816	190
June	816	190
July	810	150
August	802	100
September	802	100
October	802	100

IV. RECREATION MARKET AREA

a. Origin of Use. Since non-Federal interests have decided not to participate in recreational development at Nookagee, only minimal facilities will be provided, and these will be primarily for fisherman access. It is expected that approximately 80% of the day use will originate from within 20 miles of the project, mainly from local communities such as Fitchburg, Gardner, and Leominster. These three communities are the principal population centers in the immediate vicinity of the project, about 10 miles, and have a combined population of nearly 100,000. It is estimated that close to 1,000,000 people reside within an hour's drive of Nookagee Lake.

b. Socio-economic Characteristics. - Wholesale and retail trade in addition to industry, primarily the manufacture of fabricated metal products, paper, and wood products, furniture and machinery, account for over 80% of the employment in the project area. Two out of three people are engaged in some form of manufacturing.

Based on past and anticipated future trends, the population within the immediate zone of influence of Nookagee Lake is expected to increase about 12% by 1990 and about 30% by 2020. Most of this growth is anticipated to take place in the smaller towns and suburban communities and in Leominster.

Today, people have more leisure time than ever before and with improved transportation, higher incomes and in some cases shorter work weeks, have more time available for recreational pursuits. In the Nookagee area, there is a need for more public recreation opportunities, especially those which are water oriented. Many of the existing lakes and ponds are used for domestic and industrial water supply purposes and are not available for public recreation. Nookagee Lake offers the potential for an additional water resources development primarily suited to fishing and some boating.

c. Existing Recreation Areas. - There are three State Forests, one State Reservation and one Corps of Engineers Flood Control Reservoir within 20 miles of Nookagee Lake. Willard Brook State Forest in Ashby and Otter River State Forest in Winchendon offer both camping and bathing in addition to picnic facilities as does the Lake Denison Recreation Area at Birch Hill Dam. Leominster State Forest in Leominster offers facilities for bathing

and picnicking and Wachusett Mountain State Reservation in Princeton has picnic facilities. Most of the land at Birch Hill Dam, including Lake Denison, is leased to the Massachusetts Department of Natural Resources for conservation and management in conjunction with the adjacent Otter River State Forest.

d. Recreation Demand and Project Capability. - With an increasing population and more leisure time there is an ever growing need for more public recreation opportunities and Nookagee Lake can meet part of that need. Since non-Federal interests have decided not to participate in any recreational development at this project, only minimal facilities will be provided. Fishing opportunities will be improved considerably and some recreational boating will be made available in addition to other forms of recreation which require no formal facilities. It is expected that this project will meet anticipated recreation needs on a limited basis.

V. ANTICIPATED PUBLIC USE

a. Recreation Attendance. - Recreational use of Nookagee Lake is expected to consist primarily of fishing due to the fact that only minimal facilities are planned. Some incidental hunting, hiking and boating may take place, but fishing is estimated to account for about 95% of the annual public use. The population of the area within a 20 mile zone of the project is about 250,000 people. The average annual attendance at Nookagee Lake from these market area residents is projected to be about 14,000. Visitation is expected to remain relatively stable unless additional recreation facilities are provided in the future.

b. Land Acquisition. - The Bureau of Sport Fisheries and Wildlife in their report of 11 May 1972, which is designated as Appendix A, has recommended that public access to the two mile segment of Phillips Brook below Nookagee Dam be guaranteed in the future by either land acquisition or easements in order to realize maximum recreational fishing benefits. This will mitigate the loss of the 1 3/4 miles of stream fishing to be inundated by the lake. Trout fishing benefits from flow augmentation cannot be assured without public access and therefore it is considered desirable and essential to acquire easements or ownership of a strip about 100 feet wide along the banks of Phillips Brook for about 1.5 miles below the proposed dam for fishery enhancement purposes.

VI. PLAN OF DEVELOPMENT

a. Suitability for Recreation Use. - Nookagee Lake will not be particularly well suited for general day use recreation activities due to the fluctuating water level in the summer caused by the water quality releases. However, there is good potential for both warm and cold water fishing and the demand for better public fishing opportunities, particularly cold water (trout), is high. Good access to the area will be provided by the relocated Route 12 and several local roads.

b. Proposed Recreation Development. - During reformulation of the Nookagee and Whitmanville projects it was decided that Whitmanville Lake was a more suitable site for extensive recreation development since it offered a stable pool, a better shoreline and more adequate land for development. It has therefore, been agreed by OCE, NED, Bureau of Sport Fisheries and Wildlife, and the Commonwealth of Massachusetts that only minimal recreation facilities be provided at Nookagee Lake. It was further agreed by all parties that the facilities should be primarily oriented to fishing. The Commonwealth of Massachusetts has indicated that due to financial considerations and pool drawdown they do not wish to participate in any extensive development and consequently recommend the minimal facilities.

Recreation development will be limited to boat launching ramps and parking at three locations where local roads enter the reservoir area. Fred Smith Road will be the major access area since a boat ramp can serve all pool stages and enough suitable land is available for parking to accommodate 40 to 50 cars. Minimum sanitary facilities and a turnaround will also be located here. Adequate access from Dean Hill Road will serve a boat ramp at the upper end of the project during periods when the pool elevation is reasonably high (above 810 feet msl). No other facilities except parking for about 20 cars will be provided here since this area will receive significant use only during the early spring when fishing pressure is heavy. The third access point at Bean Porridge Hill Road is on an unimproved and lightly used road and is not expected to be a particularly desirable or accessible access area. Parking for up to 10 cars will, however, be provided here. Since these latter two sites provide less favorable conditions for development their usage will not be emphasized and facilities will consist of only limited informal parking, and turnarounds where necessary.

A scenic overlook area will be provided on relocated Route 12 east of Nookagee Dam. Adequate parking for about 15 cars and possibly several picnic tables will be available for the visiting public. Sanitary facilities will not be provided at the overlook area.

c. Fish and Wildlife Conservation. - Phillips Brook is stocked annually with brook and brown trout by the Massachusetts Division of Fisheries and Game on a "put and take" basis. Nookagee Dam will inundate about 1 3/4 miles of trout stream and create a minimum pool of about 100 acres in an average year. It is expected that a cold and warm water fishery will be established with largemouth bass, yellow perch, pickerel, and bullhead providing the bulk of the warm water fishing and brook trout the cold water fishing.

With flow augmentation downstream of the dam in July and August the trout season will be extended by about two months and fishing will be considerably improved. However, the Bureau of Sport Fisheries and Wildlife has advised that fishery benefits due to flow augmentation will occur only if public access is assured. Therefore, it is planned to acquire either easement or ownership for about 1.5 miles, of a 100 foot wide strip along

Phillips Brook for public access. The 1.5 mile reach of stream below the dam is bordered by relatively undeveloped land containing four homes. The extent of access will be approximately 100 feet wide, including the brook, with the land varying between 20 to 40 feet each side of the stream banks. Present plans do not include taking easements or land from any of the four existing improved properties. The acquisition of easement or ownership will mitigate the loss of about 1 3/4 miles of trout stream to be inundated by the project. Route 12 runs close to Phillips Brook in many places and small off-road parking areas could easily be developed once access to the brook is insured.

The reservoir area provides fair to good habitat for white-tailed deer, ruffed grouse, woodcock, snowshoe hare, gray squirrel and ring necked pheasant, which are stocked. Many other non-game animals and birds are found in the area. However, Nookagee reservoir will cause the loss of about 220 acres of wildlife habitat while at the same time creating some waterfowl nesting habitat amounting to about 45 acres. Standing timber will be left in this 45 acre area in the upper end of the reservoir to provide nesting sites and cover for waterfowl, as recommended by the U.S. Fish and Wildlife Service.

VII. COORDINATION WITH OTHER AGENCIES

While developing a plan for the recreational use of Nookagee Lake, the following Federal, State and local agencies and interests were consulted and some of them offered suggestions, assistance, recommendations and comments concerning the conservation, fish and wildlife and water quality aspects of the project as well as the recreation potential.

Bureau of Sport Fisheries and Wildlife
Massachusetts Department of Natural Resources
Massachusetts Division of Fisheries and Game
Massachusetts Department of Public Health
Environmental Protection Agency
Nashua River Watershed Association
Montachusetts Regional Planning Commission
Nashua River Reservoir Company
City of Fitchburg
Town of Westminster
Town of Ashburnham

VIII. MANAGEMENT AND COST SHARING

The entire Nookagee Lake project area will be operated and maintained by the Corps of Engineers, including the minimal recreation facilities. Flood control and water quality discharges will be regulated by the Corps and coordinated with releases from Whitmanville Lake. Permanent Corps personnel will be assigned to this project.

Development of recreational facilities will be financed entirely by the Federal Government. There will be no cost sharing at this project due to the lack of non-Federal participation and project reformulation resulting in the provision of only minimal recreation facilities.

IX. ENVIRONMENTAL QUALITY

Extensive measures will be undertaken to preserve the environmental integrity of Nookagee Lake before, during and after project construction. Landscape architectural plans and procedures for controlling various forms of water, air and noise pollution have been developed as a result of environmental concern.

Architectural design of facilities and structures will be based on a consideration of the rural environment. Several principles will be applied during project design to insure that adequate land is acquired for all project needs; that complete site plans for the entire project including temporary construction facilities are included in the final design; that plans for the protection and preservation of existing natural assets including vegetation and land forms are considered; and that plans for the use of plant material for landscaping and other aesthetic purposes are developed.

Development features will be designed to blend with existing site characteristics, so that structures, walks, roads, trails, parking areas and other elements are compatible with the natural environment.

Special precautions will be taken during construction to avoid soil erosion by preventing unnecessary destruction of stabilizing vegetation, controlling surface runoff and providing settling basins to remove silt from water before it is discharged into the stream.

Dust control, especially in dry weather, will be accomplished by making use of water and dust palliatives during project construction.

Clearing and stripping will be kept to the minimum necessary with burning of cleared material not allowed. Trees will be cut into sawlogs and smaller material processed by woodchippers. Stripping of organic surface soil will be carefully done to avoid erosion. Most of the area to be inundated (150 acres) will be stripped of organic material to protect water quality.

Sequential borrow operations are planned to avoid exposure of excavated earth surfaces to water erosion. Limited areas will be cleared, stripped, excavated, graded and revegetated in a series pattern instead of waiting until all borrow operations are complete before stabilizing the surface of the area.

Careful consideration will also be given to measures necessary to prevent possible pollution from concrete spillage, concrete curing water, oil and fuel spillage as well as excessive noise from construction equipment. Contractor storage and equipment maintenance areas will be designated by the government with controlled grading and drainage. Strict sanitation measures will be enforced concerning proper sewage disposal from personnel sanitary facilities constructed by the contractor.

X. COST ESTIMATES

There are no separable lands or operation, maintenance and replacement costs for recreation development at Nookagee Lake. The estimated cost (all Federal) of recreation development and facilities is $15,000 including contingencies but not including E&D and S&A.

Access Area	Facilities	Cost
Fred Smith Road	Parking (40 cars)	$7,000
	Turnaround	1,000
	Boat Ramp (Road Improvement)	2,000
Dean Hill Road	Parking (20 cars)	2,000
	Boat Ramp (Road Improvement)	1,000
Bean Porridge Hill Road	Parking (10 cars)	1,000
	Boat Ramp (Road Improvement)	1,000
	Construction Cost	$15,000
	E&D and S&A	3,000
	Total Cost	$18,000

Portable, rented chemical toilets will be made available as necessary to insure adequate sanitary facilities. Annual rental costs are expected to be about $150 each.

XI. RECREATION BENEFITS

Average annual recreation benefits at Nookagee Lake are estimated at approximately $35,000, of which fishing accounts for nearly $34,000.

Activity	User Days	Unit Value	Benefits
Cold Water Fishing	2,000	$4.00	$ 8,000
Loss of Existing Cold Water Fishing	-2,000	4.00	-8,000
Warm Water Fishing	11,300	3.00	33,900
Small Game Hunting	100	2.00	200
Other General Recreation	600	1.50	900

CORPS OF ENGINEERS — U. S. ARMY

A B C D E F G H

N 594 000 E 502 000 N 592 000 N 590 000 E 504 000 N 588 000 N 585 000 E 506 000 N 584 000

E 500 000 E 498 000 E 496 000

1 2 3 4 5 6 7 8

RELOCATED ROUTE 12

FLOW LINE AT SPILLWAY
CREST EL. 835.0

OVERLOOK AREA

SPILLWAY

DUDLEY RD

McENTIRE RD

FRED SMITH ROAD ACCESS AREA

FRED SMITH ROAD

FITCHBURG WESTMIN STER

ASHBURNHAM WESTMIN STER

DEAN HILL ROAD ACCESS AREA

DEAN HILL ROAD

JEWEL HILL ROAD

MAIN STREET

ASHBURNHAM

PHILLIPS BROOK

STATE

BEAN PORRIDGE HILL RD

SPUR ROAD

BEAN PORRIDGE HILL ROAD ACCESS AREA

DAM
TOP EL. 846.5

BORROW AREA

FLOW LINE
WATER QUALITY POOL
EL. 816.0

FLOW LINE AT SPILLWAY
CREST EL. 835.0

POTATO HILL RD

NOTES:
1. 2000 FT. GRID BASED ON MASS. RECTANGULAR COORDINATE SYSTEM
2. DATUM IS MEAN SEA LEVEL 1929

RESERVOIR PLAN
SCALE: 1"=400'

GRAPHIC SCALE
1"=400' 400' 0 400' 800'

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY J B M | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
RESERVOIR PLAN
PHILLIPS BROOK MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

APPENDIX C

LETTERS OF COMMENT AND CONCURRENCE

APPENDIX C

LETTERS OF COMMENT AND CONCURRENCE

NOOKAGEE LAKE

NORTH NASHUA RIVER BASIN, MASSACHUSETTS

CONTENTS

FEDERAL POWER COMMISSION
REGIONAL OFFICE
346 BROADWAY
NEW YORK 13, NEW YORK 10013

January 30, 1964

Division Engineer
U. S. Army Engineer Division, New England
424 Trapelo Road
Waltham, Massachusetts

Subject: Proposed Reservoir Projects,
North Nashua River Basin

Dear Sir:

Reference is made to your letter of October 18, 1963, requesting our comments on the hydroelectric power potentialities of six proposed reservoir projects located on the North Nashua and Baker Brook tributaries of the Merrimack River.

A review of the pertinent project data furnished with your letter indicates that only a relatively small amount of hydro power could be developed at any of the proposed projects (less than 100 kw). This is due largely to the limited run-off provided by the small tributary drainage areas involved, which range from 1.7 to 17.5 square miles.

It is concluded, therefore, that none of the six proposed reservoir projects are adapted to the practicable and economic development of hydroelectric power in conjunction with other project purposes.

Sincerely yours,

D. J. Wait
Regional Engineer

EXHIBIT C-1

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE

612 J.F.K. FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203

IN REPLY REFER TO:

Whitmanville and Nookagee Lake Projects

August 19, 1971

Colonel Frank P. Bane
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Colonel Bane:

Receipt is acknowledged of your letter dated July 2, 1971 regarding the status of the Whitmanville and Nookagee Lake projects.

There is a Federal-aid route in the area that will be affected by the proposed projects. Under the Federal-State relationships all work is initated by the State Highway Departments. The State of Massachusetts' Department of Public Works, has the responsibility of the design, construction and maintenance of Federal-aid routes.

We understand that the Corps has had preliminary contact with the State regarding the relocation of several routes in the project area. We do not have any comments at this time but probably will as more details are developed.

If during the development of the detailed plans, we can be of help, do not hesitate to contact our office.

The opportunity of expressing our comments at this time is appreciated.

Very truly yours,

H. Pearlman

H. Pearlman
Division Bridge Engineer

EXHIBIT C-2

UNITED STATES GOVERNMENT
ENVIRONMENTAL PROTECTION AGENCY
REGION I
NEW ENGLAND BASINS OFFICE
240 HIGHLAND AVENUE
NEEDHAM HEIGHTS, MASSACHUSETTS 02194

August 3, 1971

Mr. John Wm. Leslie
Chief, Engineering Division
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

I have your letter of July 2, 1971 describing changes in the design of the proposed Whitmanville and Nookagee reservoir projects in the North Nashua River Basin, Massachusetts. The changes involve the deletion of water supply storage from both sites, the inclusion of 3,800 acre feet of storage for low flow augmentation for water quality (3,000 acre feet of which would be at the Nookagee site), and the transfer of the main recreational development from the Nookagee site to the Whitmanville site.

The proposal, as outlined, is consistent with the recommendations contained in our report, "Water Quality Control Study, North Nashua River Basin," dated April, 1968, and our letter of October 31, 1969.

It should be noted that the river flow values contained in the above letter are total river flows. Maintenance of this regime will require coordinated releases from existing reservoirs owned and operated by local interests as well as from the Nookagee and Whitmanville projects. Firm assurance that the existing reservoirs will be operated in an appropriate fashion is essential if the water quality benefits from the Federal reservoir projects are to be realized.

FOR THE REGIONAL ADMINISTRATOR:

Sincerely yours,

Bart Hague

Bart Hague
Chief of Planning

EXHIBIT C-3

ENVIRONMENTAL PROTECTION AGENCY

424 Trapelo Road Bldg. 138 West
Waltham, Massachusetts 02154

October 13, 1972

Mr. John Wm. Leslie
Chief, Engineering Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Reference is made to our letter of August 21, 1972 relative to the design memorandum for Nookagee Reservoir, streamflow requirements for the Nashua River Basin, a pending flow agreement and EPA policy modifications which would effect the quantity of desirable flow releases from the proposed projects. The purpose of this letter is to apprise you of the status of the above factors and to provide you with information for planning purposes.

The agreement between EPA, Weyerhaeuser Company, Nashua River Reservoir Company and the City of Fitchburg to provide a continuous flow of 12 cfs measured at the Arden Mill Dam has been consummated. A streamflow gaging station is being established at this location by the U.S. Geological Survey in cooperation with the Nashua River Program and the Massachusetts Division of Water Resources to monitor streamflows.

As you recognize several key variables determine the quantity of streamflow required for water quality control in the Nashua River Basin. The provisions of the pending Federal Water Pollution Control Act, pending modifications in the EPA policy regarding streamflow for water quality control and future paper production levels constitute important considerations. Our best judgement at this time is that the following total river flow (measured at the Leominster Gage) would be necessary to achieve dissolved oxygen standards in the river and maintain an adequate environmental streamflow: 43 cfs in May and October; 46 cfs in June and September and 52 cfs in July and August.

As the above variables are further clarified we will consult with members of your staff. We look forward to working with you as the project design progresses.

FOR THE REGIONAL ADMINSTRATOR:

Sincerely yours,

Walter M. Newman
Chief
Water Quality Branch

EXHIBIT C-4

COMMENTS OF THE COMMONWEALTH OF MASSACHUSETTS

The Commonwealth of Massachusetts

Water Resources Commission

15 SCHOOL STREET, BOSTON 02108

OFFICE OF THE DIRECTOR

December 2, 1965

William F. Cassidy
Lieutenant General, USA
Chief of Engineers
Department of the Army
Washington, D.C. 20315

RE: North Nashua River Project in Massachusetts.

ENGCW-PD

Dear Sir:

The Commonwealth of Massachusetts is vitally interested in the multi-purpose development proposed by the New England Division, Corps of Engineers, on the North Nashua River in the vicinity of Fitchburg and Leominster, Massachusetts.

The Commission points out that the area is badly in need of flood control, additional industrial water supply, and recreational water. This area has been critically short of water during the current drought and it is evident that, even with increased public water supplies which may be provided in the next few years, all possible sources of water for industry and recreation should be developed as soon as possible.

This Commission will support any State legislation necessary to carry out the local requirement of the project.

It is urged that the North Nashua River Project be authorized at the earliest possible date.

Very truly yours,

Malcolm E. Graf

Malcolm E. Graf
Director and Chief Engineer

MEG/n

EXHIBIT C-5

FRANCIS W. SARGENT
GOVERNOR

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE DEPARTMENT
STATE HOUSE, BOSTON 02133

July 23, 1971

Colonel Frank P. Bane
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Bane:

Thank you for your status report on the North Nashua project. I enthusiastically support your efforts to obtain a significant water based recreation area at Whitmanville which will help serve the Gardner-Fitchburg-Leominster area.

I was pleased to read in the Environmental Guidelines for the Civil Works Program of the Corps of Engineers that under "planning (f)," if a measure has "a detrimental net effect on the environment, the Corps will seek means for modifying it to ameliorate its environmental effects." This policy assumes importance at the Nookagee Site, because "drawdowns over five feet are considered excessive and detrimental to recreation by exposing large, unsightly areas along the shoreline," and I have been informed that the estimated average annual drawdown here will be fourteen feet.

Though this project will be used primarily for flow augmentation, steps should be taken to prevent esthetic deterioration of the site. Your environmental statement acknowledged this potential problem, and discussed the possibility of exploring measures to alleviate "odor and visual problems." I recommend that great attention be given to this in the final design, construction and operation of the Nookagee Reservoir. Acquisition and enhancement of buffer areas and alteration of the pool bottom should also be considered.

EXHIBIT C-6

Our Department of Natural Resources informs me that there is a need for flow augmentation to help meet water quality standards in the North Branch of the Nashua River. They recommend that, in order that flows released for this purpose do not merely become a new source of process water for industrial use, the Corps of Engineers should insure that the federally augmented flows pass down the Nashua free from withdrawal uses in the critical areas. This might be accomplished by a guarantee of the maintenance of specific minimum instantaneous flows in the natural river channel.

I assure you that my office and the Department of Natural Resources will cooperate in your efforts to enhance and preserve the environmental quality of these areas.

With best wishes,

Sincerely,

Francis W. Sargent

THE COMMONWEALTH OF MASSACHUSETTS

WATER RESOURCES COMMISSION

STATE OFFICE BUILDING, GOVERNMENT CENTER

100 CAMBRIDGE STREET, BOSTON 02202

OFFICE OF THE DIRECTOR
DIVISION OF WATER
POLLUTION CONTROL

January 28, 1972

Mr. John S. McGlennon
Regional Administrator
Environmental Protection Agency
J. F. Kennedy Federal Building
Boston, Massachusetts 02203

Re: Low Flow Augmentation
North Nashua River

Dear Mr. McGlennon:

In its study of the North Nashua River for flood control and allied purposes, the Corps of Engineers has recommended construction of certain multiple-purpose reservoirs. These reservoirs have been authorized and the Corps is currently in the design stage of two: Whitmanville and Nookagee. The proposed reservoirs are being designed to include storage for flow augmentation which had been previously suggested and justified by your predecessor agency, the Federal Water Quality Administration.

At a recent meeting of the Management Board of the Nashua River Program, a member of your staff stated that your agency no longer endorses storage of water for flow augmentation in these two reservoirs. I trust this is not the considered opinion of your agency.

I am aware, of course, that storage for regulation of streamflow for the purpose of water quality control may not be provided as a substitute for adequate treatment or other methods of controlling waste at the source (Section 3 (b)(1) of Public Law 87-88). I consider that the term "adequate treatment" is more than being met by the proposed design of the two, $30 M Fitchburg treatment facilities which will afford a very high degree of treatment utilizing the most modern technology available. Studies indicate that, even with this high degree of treatment the State Water Quality Standards will not be met, thereby justifying the inclusion of storage for flow augmentation on this basis alone.

EXHIBIT C-7

Beside requiring supplemental flows to meet the assigned Water Quality Standards, additional flow in the North Nashua River will also enhance the recreational and fisheries resources inherent in this stream as well as the aesthetics of the basin.

I sincerely request you to give careful consideration to the above before you reach any decision relative to the elimination of storage in the two proposed Corps reservoirs. I would be happy to have members of my staff meet with their counterparts in your agency to study this matter in depth.

Very truly yours,

. . . . . .
Thomas C. McMahon
Director

TCM/WAS/lw
cc: Chief, Engineering Division, Corps of Engineers, 424 Trapelo Road, Waltham, Massachusetts 02154

NEW ENGLAND REGIONAL COMMISSION
55 COURT STREET
BOSTON, MASSACHUSETTS 02108

August 30, 1971

Mr. John W. Leslie, Chief
Engineering Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

Thank you for your letter dated August 11, 1971 advising the Commission of the current status of the Whitmanville and Nookagee Lake projects to be located in Westminster and Ashburnham, Massachusetts.

As you know, the Commission is sponsoring and funding the Nashua River Program (a demonstration in water quality management) and has set up an office in Fitchburg, Massachusetts. Since both of these projects deal with the Nashua River Basin, I have asked John Bellizia, Project Director for the Nashua River Program, to comment on them.

Attached is a copy of his letter of August 19, 1971. The Commission concurs with Mr. Bellizia's comments.

Sincerely,

Richard E. Wright

Richard E. Wright
Executive Director

Attachment

EXHIBIT C-8
sheet 1

NASHUA RIVER PROGRAM
76 SUMMER STREET – ROOM 117
FITCHBURG, MASSACHUSETTS 01420

TELEPHONE: 345-1104

19 August 1971

Mr. John W. Leslie
Chief, Engineering Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

This office is in receipt of your communication of 11 August 1971, regarding the Whitmanville and Nookagee Lake Projects.

In connection with the revitalization of the Nashua River, low flow augmentation will be necessary, even after the wastewater treatment works now being designed are constructed. There is no doubt in my mind that public opinion will demand that water quality in the North Nashua River exceed the stream classification standards presently assigned by the Massachusetts Division of Water Pollution Control.

The proposed water storage facilities at Whitmanville and Nookagee will provide water for low flow augmentation. As you have stated, the drawdown at Nookagee will be such as to interfere with recreational development at the site. In my opinion, consideration should be given to creation of a small impoundment of water below the proposed Nookagee spillway, using the water released for low flow augmentation to create a flow-through bathing and swimming pool.

We agree with your office on the need for the Whitmanville and Nookagee projects insofar as water quality in the Nashua River is concerned and urge that the necessary works be installed as soon as possible.

Sincerely,

John A. Bellizia
Director

EXHIBIT C-8
sheet 2

NEW ENGLAND RIVER BASINS COMMISSION
55 COURT STREET · BOSTON, MASSACHUSETTS 02108
PHONE: (617) 223-6244

July 26, 1971

Mr. John Wm. Leslie, Chief
Engineering Section
Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

Reference is made to your letter of July 2, 1971, requesting comments on a revised plan for the proposed Witmanville and Nookagee resevoirs on the North Nashua River Multi purpose project.

I am pleased to say that after examing the site plans and your letter, you have come forth with a sensible solution to the problem created when the city of Fitchburg and the Industry declined to participate in the water supply features of the original plan.

In so far as EPA through its predecessor FWQA has requested low flow augmentation for water quality control, I would expect that this portion of the project would be paid through Federal Funding. If not, then we would have to explore the possibility of state participation. In any event should low flow augmentation be dropped from the project for any reason, such as high quality treatment plant discharges, it would be most desireable to provide the flows for the main stream where releases of only 12 million gallon per week are required, equal to 1.1 c. f. s., by the enabling legislation for the Wachusett Resevoir which has a tributary area of about 118 square miles.

I sincerely hope that your new real estate acquition requirements do not put this worth while project out of reach on the benefit cost ration side of the picture.

Thank you for this opportunity to comment on this project.

Sincerely yours,

Malcolm E Graf

MG:bor

Malcolm Graf

EXHIBIT C-9

OFFICE OF THE MAYOR
FITCHBURG, MASSACHUSETTS
01420

WILLIAM G. FLYNN
MAYOR

THOMAS J. CONRY, JR.
ADMINISTRATIVE ASSISTANT

MRS. NANCY A. MAYNARD
SECRETARY

November 25, 1969

Senator Edward Kennedy
Senate Office Building
Washington, D. C.

Dear Senator Kennedy

During your recent visit to the Fitchburg area to inspect the pollution of the Nashua River, you asked that I write to you relative to the need to include sufficient water storage capacity for low flow augmentation of the Nashua River as part of the Army Corps of Engineers North Nashua River Flood Control Project.

It is my understanding that the Corps of Engineers is prepared to begin the design phase of the project pending allocation of design funds. However, since this project (by city choice) will not include domestic water supply, it appears that it might have lost a priority rating.

The Whitmanville, Nookagee, and Monoosnoc Dams are vitally needed as flood control measures for the North Nashua River, and inclusion of sufficient storage capacity to assure water for low flow periods is critical to the effectiveness of the entire pollution abatement program.

I would suggest that for more detailed information on this project your office contact:

Colonel Frank P. Bane, Division Engineer
New England Division
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

EXHIBIT C-10

Your continued interest and strongest intercessions are important for the success of the Nashua River Clean-Up Program.

With every good wish, I remain

Very truly yours

William G. Flynn

William G. Flynn
Mayor

WGF/nm

cc: Alan E. Rimer
George Lanides
Marian Stoddart

1 May 1972

Corps' Response to Comments from Board of Selectmen, Town of Westminster, Mass.

Comment A - The dams would inundate 260 acres of land. Additional land would be taken for sluiceways, roads, and to provide fill.

Response - Comment is basically correct.

Comment B - 54 families would lose their homes.

Response - Comment is basically correct.

Comment C - Land and buildings to be removed from the tax rolls have a current assessed valuation of $731,000. This would mean an increase of $1.75 on the tax rate.

Response - The assessed valuation of property to be acquired for the project of $731,000 agrees very closely with the Corps' estimate. The anxiety of local interests over loss of taxable land has been pursued with the Water Resources Commission of the Commonwealth of Massachusetts. At a meeting with Westminster Town Officials, a representative of the State pointed out that the Commonwealth reimburses some eight areas annually for loss of taxes resulting from Corps' projects. The reimbursement is not automatic; a special measure would have to be approved by the State Legislature.

Comment D - The project would destroy 8.25 miles of free-flowing stream. Fish spawning grounds would be ruined and the ecology of woodlands surrounding the dams would be severely altered.

Response - The Whitmanville and Nookagee Lake projects would replace 3/4 and 1-3/4 miles of stream respectively with lakes of equivalent length. The 8.25 miles cited in the comment is in error. The environmental impact of the Whitmanville and Nookagee Lake projects has been of concern to this office; consequently, this office did hire a consultant with expertise in this field to assess both projects. The study was performed by New England Research, Inc. of Worcester, Massachusetts and the report has been made part of the Environmental Impact Statements (EIS). The final EIS for Whitmanville is on file with the Council on Environmental Quality and was released for public usage on 14 April 1972. The EIS for the Nookagee Lake Project is presently being prepared. The report by

EXHIBIT C-11

the consultant factually assess both projects impact on terrestrial and aquatic habitats. The "General Discussion and Summary" as contained in the report is inclosed. The detrimental effects of the projects have been carefully weighed and although undesirable are considered reasonable trade-offs for the benefits attained from the projects. The 37 existing Corps of Engineers' flood control reservoirs in New England indicate there is little damage to woodlands surrounding the reservoirs and are positive proof that there are minimal changes to the ecology.

Comment E - The dams would not provide new lakes for recreation. The new lake formed on the Phillips Brook would not be usable by the public at all. Its water would be released during the summer, leaving 150 acres of foul-smelling mudflats.

Response - The Nookagee site, on Phillips Brook, will provide a body of water with a surface area of 190 acres. The full pool will be available from the beginning of April to the end of June. From the end of June to Labor Day water will be released to improve the flows and the quality of water in the North Nashua River. After Labor Day the stored water releases will be stopped and the lake will be refilled as rapidly as possible while maintaining a minimum desired stream flow in Phillips Brook. The rate of release of the impounded water and the extent of drawdowns will be dependent upon the amount of precipitation and runoff in the basin. In extremely dry years (1 in 10 year frequency) the drawdown would commence about the 1st week of June and by Labor Day could result in an elevation drop of 26 feet and would expose approximately 140 acres. Similarly the rainfall on an expected frequency of 1 in 10 years is expected to be such that no drawdowns will occur and a full pool will be available all year long. Between these two limits, the drawdowns for any one year would vary according to the precipitation. Such releases during the period of June to September will expose certain areas of impoundment bottom. The exposed pool bottom areas are considered an undesirable environmental effect, since it would be a more ideal situation if the pools could be maintained constantly at a stable level. The pool bottom will be naturally sloped to allow good surface drainage, thus preventing water from remaining on the surface. In addition, the organic material overlying impoundment bottom areas subject to pool fluctuations will be removed exposing the underlying gravel surface. The exposed gravel surface will be considerably more pleasing aesthetically than the organic overburden. The State's present policy of stocking the brook is based upon a "put-and-take" basis with little expected liklihood that the fish will survive in the brook on a year-round basis. The flow in the brook is usually reduced naturally during the

summer months such that the fish do not survive. The project when completed will prevent such low flow condition and will supply, particularly during the critical summer months, an abundant supply of high quality water to support year-round fishing. The 190 acre lake will provide excellent opportunities for fishing on a "put-and-take" basis since the lake will always be full during the heaviest fishing pressure. A minimum conservation pool is provided to insure that the lake will never be drawn dry.

Comment F - Water would be released from the Whitmanville Reservoir as well, also leaving mudflats. The Army Corps of Engineers has proposed recreation facilities here - built on the existing shoreline of the reservoir. These facilities (which could be built without the dam) would not be free. Cost of their maintenance would be deducted from the Town "Cherry Sheet".

Response - The existing Westminster Reservoir has a surface area, when full, of 120 acres and a storage volume of 1,150 acre feet (1 acre - 1 foot deep). The paper industries, the present owners, utilize this storage as process water. For the average year approximately 55% of the storage is utilized by Labor Day and approximately 60 acres of impoundment bottom is exposed. The drawdowns continue after Labor Day until the stream flows exceed the demands by the paper industry. The excess water condition normally occurs during the spring snowmelt season. Drawdowns frequently expose 80 to 90 acres of shoreline for extended periods. The present owners do not permit public usage of the lake.

The Whitmanville Dam is to be built at a point 3/4 miles downstream of the existing Westminster Dam. The Corps' plan envisions retaining the existing dam and to operate a two pool system. During the spring and early summer months a combined pool surface of 196 acres will be available for fishing. During the summer months the upper pool of approximately 120 acres will be used as the primary recreation area and the pool between the two dams as storage to meet industrial demands. The upper pool, therefore, will remain a stable pool all summer long and will be supplemented with excellent recreational facilities for public use. Recreational uses will include fishing, boating, swimming, picknicking, hiking, as well as other active pursuits. Exposure of the impoundment bottom, with the project, will occur primarily in the lower pool during the summer months and may approach 40 acres by Labor Day. By 1 November the exposed bottom area is expected to be 80 acres and during serious droughts the area of exposure may exceed 80 acres. At Whitmanville as well as Nookagee, the exposed bottoms are naturally sloped such as to allow good surface drainage and the organic material will be similarly removed.

Except for the recreational aspect, 100% of the cost for construction and operation of the two reservoirs would be borne by the Federal Government. The separable first cost of adding recreational features would be shared equally between the Federal Government and the Commonwealth. The State must also bear all costs of operation and maintenance of the recreational facilities. Based upon information furnished by the Massachusetts Department of Natural Resources, all revenue obtained from recreation facilities in the State (outside the Metropolitan District Park Commission) is placed in a special fund. Cost of operation, maintenance and improvements are taken from that fund. Any deficit that may occur, regardless of where the facility is located, is shared by all 314 communities outside the M.D.P.C. Consequently, any deficit in the cost of operating and maintaining the recreational facilities at the Whitmanville Lake project will be shared equitably by all the 314 communities and not solely by the community where a project is located.

Comment G - Water released from the dams would be used to dilute sewage in Fitchburg and Leominster. Water treatment plants can do the job at less cost. Westminster is being asked to give up land and water to clean the water of downstream cities.

Response - Flow augmentation is not a substitute for adequate treatment of pollution but is intended to encourage streamflow regulation for the purpose of water quality control in concert with adequate treatment. The Environmental Protection Agency and its predecessor agencies requested flow augmentation based upon what we consider sound reasoning. The 1968 study of the North Nashua River by EPA's predecessor agency, the Federal Water Pollution Control Administration, showed that even with treatment plant efficiencies of 90%, there is a strong need for flow augmentation. The most up-to-date treatment processes known have their limitations and cannot alone solve the river's problem. The design treatment process for the West Fitchburg waste-water treatment plant was changed from an activated sludge process to a physical-chemical process in hopes of obtaining a higher level of purification. The process is considered an advanced facility utilizing some of the best available technology. A check of the test data complied from the pilot plant investigations indicate that, even under optimum operating conditions associated with such testing procedures, the reduction of BOD varies from a high of 100 percent to a low of 47 percent. The average of the test data was 86 percent BOD reduction.

This is the key to understanding the need for low flow augmentation in conjunction with waste-water treatment: a wastewater plant, no matter what the degree of sophistication employed in its design, cannot be depended upon to run continuously at its peak design removal

capability. The great number of variables affecting the actual operation of a treatment plant are such that it would be totally poor engineering and basically unsound planning to base a water pollution abatement program solely on the assumption that a treatment plant will operate at maximum design capability at all times, or even most of the time.

Comment H - An independent environmental expert studying the project has reported that the Corps of Engineers has greatly over-estimated flood dangers. The dams are being built to protect against a flood twice as large as the largest flood in the history of the region.

Response - The views of the "independent environmental expert", referred to in the Selectman's comment, are familiar to this office. This office was requested by the Nashua River Watershed Association to review the report prepared for them by the environmentalist. The environmentalist's assessment of the flood danger was found to be unacceptable by existing criteria; as evident by subsequent paragraphs.

Statistical procedures for determining flood discharge frequencies are many and varied. Many of the methods provide nearly identical results, whereas others are quite divergent. Because of the inconsistency in methods used by various Federal agencies, in 1966 a comparative study was made of the five most commonly used methods of flow frequency analysis. The five individual methods considered were the Hazen Method, Pearson Type III Method, Gumbel Method, Gamma Distribution Method and Graphical Distribution-free Method. The study was made under the auspices of the Hydrology Interagency Committee on Water Resources and was made on behalf of the following participating agencies: Agriculture Research Service, Forest Service, Soil Conservation Service, Corps of Engineers, Bureau of Public Roads, Weather Service, Bureau of Reclamation, Geological Survey, Bureau of Mines, Bureau of Land Management, Public Health Service, Federal Power Commission and the Tennessee Valley Authority. The results of this study are reported in "Methods of Flow Frequency Analysis", Hydrologic Activities Bulletin No. 13, April 1966.

Subsequent to the above study, the Water Resources Council, Hydrology Committee, adopted the Pearson Type III Method and in December 1967 published Bulletin No. 15, entitled: "A Uniform Technique for Determining Floodflow Frequencies". In this Bulletin, the Council set forth the procedure for use in all Federal planning involving water and related land resources. Until another method is adopted, the New England Division must continue, as it has in the past, to use the Pearson Type III Method. We consider this method to be the most accurate.

The two greatest floods of record on the North Nashua River at Leominster occurred in March 1936 and September 1938. The Pearson Type III Method indicates these two floods to have recurrence intervals of 80 and 30 years, respectively. Using the same flow records, the environmental expert's Gamma Method indicates recurrence intervals of about 1,500 and 80 years, respectively. Only history will prove

which frequency is more correct. However, any method indicating both a 1,500 and 80 year event in only a 35-year period of record must be considered questionable.

Prior to 1954, the flood of record on the Blackstone River at Northbridge, Massachusetts was the March 1936 event. As on the North Nashua River, the 1936 flood on the Blackstone River was much greater than any other known event, the flow being two times greater than the next largest flood, the September 1938. At that time, based on the record, one might conclude that a flood as great as the 1936 was extremely rare. However, in August 1955 the Blackstone River experienced a flood flow two times greater than the 1936 flood.

Another indicator of the rarity of a flood is the frequency of the meteorological event that produced the flood. The 1936 flood resulted from about 6 inches of rain in 24 hours, the 1938 from 7.5 inches in 24 hours. These are not infrequent storm events in the New England area. Weather Service data reveal these storms to have frequencies of about 25 years and 75 years, respectively.

The environmentalist's report suggests that the 1936 flood is too remote for design and recommends that flood protection be built for their 200-year frequency flood, which at Leominster is about 25 percent less than the record 1936 flood. This kind of logic is not new, only less conservative than usual and in our view dangerous, particularly when one views the nature of urban development in the area to be protected and the erosive and destructive flow attendant with a flood of this magnitude.

Comment I - The economic "benefit" of the dams lies largely in the development of land that is now subject to flooding. Once again, Westminster is being asked to subsidize downstream communities.

Response - The economic "benefit" of the dams lie primarily in providing flood protection for existing extensive developments in the Cities of Fitchburg and Leominster.

Comment J - Alternative measures exist. These include smaller dams, and river channel improvements, and complete water treatment plants in the cities that need them.

Response - Frequently, statements are made by individuals and groups that alternative measures exist and cite general concepts, such as, smaller dams and river channel improvements. The alternatives offered, however, should be more than in name and concept only. They should be presented and analyzed to firmly establish the feasibility of implementation and to measure the real impact of

proposed alternatives. It is a relatively easy task to conjure conceptual alternatives but the fitting of these alternatives within the engineering, economic, and environmental dictates while fulfilling positive water resource needs is the true test.

In the preparation of the 1965 report, Water Resource Development Plan for the North Nashua River Basin, the Corps did consider conceivable alternatives. It was obvious that some alternatives were not feasible and were discarded. Those that appeared to have merit were studied in detail. The alternatives were listed, evaluated and the reasons why the alternatives were discarded were stated in the 1965 report. Alternatives studied in detail included: local protection, a closed conduit supplemented by channel improvements, and a tunnel diversion supplemented by channel improvements.

The alternatives to the flood problem have been re-evaluated during preconstruction planning and remain as stated in the 1965 report. The alternative of smaller dams was considered and was not recommended since it would require more land, higher cost and would be more disruptive environmentally. In addition the basin does not have a sufficient number of suitable sites for the smaller dams. The environmental expert, cited in Comment H, discarded this alternative for similar reasons.

Comment K - The Montachusetts Regional Planning Commission has urged that other alternatives be studied. The Nashua River Watershed Association opposes the dams.

Response - As per telephone conversation (early April and 26 April 1972) with Mrs. Hugh F. Stoddart President of the Nashua River Watershed Association; the Association is not opposed to the dams. Mrs. Stoddart stated that the Association's present position is that they want the Corps to consider all alternatives prior to constructing any of the projects in order to be sure that the plan implemented is the best possible for the basin.

Comment L - In Sept. 1969, the local interests, through the Mayor of the City of Fitchburg, Mass. withdrew their support for the water supply aspects of both projects.

Response - Comment is correct.

Comment M - Studies made by Army Engineers (ref. letter 6/23/71) reveal that releases or draw downs from Nookagee Dam site for water quality purposes could be as much as 15 feet exposing large unsightly areas along the shoreline.

Response - See response to Comment E.

GENERAL DISCUSSION AND SUMMARY

Forest types of the areas of both proposed impoundments are typical of Central Massachusetts and consist of softwoods, hardwoods and mixed softwoods-hardwoods. This mixture of forest types along with a lesser area of associated agricultural land and wetlands serves as a habitat for deer, cottontail rabbits, red and grey squirrels and chipmunks. A variety of birds were observed. While no estimate of population densities was made, there is no reason to believe that the area is atypical. Carrying capacity for deer is estimated to be about one-third that of an ideal deer habitat. Both projects would result in loss of carrying capacity for about four deer.

A second impact would be the loss of trout habitat in both projects. On the other hand, the impoundments can be expected to increase the warm fish habitat. However, because of probably large fluctuations in volume and surface area, due to required drawdown, Nookagee Lake may not provide good conditions for warm water fish.

Finally, no unique habitat or site for either plants or animals have been found in this study. Appendices A and B list plants and benthic animals found in this study. Furthermore, no report of unusual habitats or species have been received from persons knowledgeable in the biology of this region. Appendix C is a list of persons consulted during the study.

APPENDIX D

PROJECT COST AND COST ALLOCATION

APPENDIX D

PROJECT COST AND COST ALLOCATION

NOOKAGEE LAKE

NORTH NASHUA RIVER BASIN, MASSACHUSETTS

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APPENDIX D

PROJECT COST AND COST ALLOCATION

NOOKAGEE LAKE

NORTH NASHUA RIVER BASIN, MASSACHUSETTS

1. General. - The Nookagee Lake Project has a drainage area of 10.8 square miles and is located on Phillips Brook in the towns of Westminster and Ashburnham, Massachusetts. The reservoir is designed for multiple use by three purposes, namely: flood control, water quality control and recreation (limited). Allocation of costs is required in order that all authorized purposes served by the project share equitably in joint savings of multiple-purpose construction.

2. Method of Allocation of Costs. - Allocation of costs of the multiple-purpose project to the purposes of flood control, water quality and recreation were made by the separable costs-remaining benefits method. Costs allocated to recreation were not apportioned to Federal and non-Federal interests since the facilities are minimal and the costs are to be borne entirely by the Government.

3. Project Description. - The project is fully described in the text of this GDM. The total reservoir storage capacity of 8,400 acre-feet consists of:

700 acre-feet to maximum Elev. 790.0 for a conservation minimum pool

3,000 acre-feet to maximum Elev. 816.0 for water quality control

4,700 acre-feet to maximum Elev. 835.0 for flood control.

Specific charges to water quality control include the cost of a monitoring system and for stripping 150 acres of impoundment bottom. The cost for obtaining access to Phillips Brook below the damsite is considered a joint-use cost since it is intended to mitigate the loss of stream fishing within the reservoir area (Ref: ER 1120-2-401). All other project features are joint use.

4. Operational Requirements. - All project features including the minimal recreational facilities will be operated by the Corps of Engineers.

5. Project Costs, Annual Charges and Benefits. -

a. Construction Costs. - The total cost of the project including lands and damages is estimated at $10,500,000 at July 1972 price levels. A detailed breakdown is shown in Table D-4. The feature of lands and damages includes the additional costs for resettlement and acquisition as required under the recently enacted "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970", P. L. 91-646.

b. Interest During Construction. - Accrued interest during construction is computed on the basis of a three-year construction period. This was derived by multiplying the total construction expenditures by the 5.50 percent interest rate and by one-half of the construction period in years.

c. Annual Charges. - A breakdown of annual charges is shown in Table D-5.

(1) Interest and Amortization. - The project is considered to have an economic life of 100 years. Interest is computed at 5.50 percent amortized over a 100-year period.

(2) Operation and Maintenance. - This item is estimated on the basis of experience with other similar projects in the New England Area. Included are costs for maintenance of the project structures and for operation of multiple-purpose project features and recreational facilities. It also includes operational procedures of the gates for flood control and water quality control, as well as the permanent operating equipment and gages for monitoring and recording the water quality and fluctuating storage in the reservoir. Further, the preparation of necessary reports to the Reservoir Control Center at NED Headquarters for regulating instructions are also included.

(3) Major Replacements. - Allowance is made for replacement of items deemed to have a usable life less than that of the project which is 100 years. Items included in the replacement cost consist of equipment used in the operation of the project such as gates, heating and ventilation systems, hydraulic system, pumps, generator, etc.

d. Project Benefits. - The dual-purpose and single-purpose projects represent the most economical alternatives in which the benefit for each of the purposes is the same as the benefit of the respective purpose in the recommended project. All the alternatives are considered at the same site as the recommended three-purpose project. The Nookagee Lake site was utilized as the most reasonable single-purpose water quality alternate for the North Nashua River Basin. The storage capacities and elevations of each of the alternatives and the recommended project are shown in Table D-1.

TABLE D-1

CAPACITIES AND ELEVATIONS

Purpose (1)	Storage In Acre-Feet	Storage In Inches of Runoff	STORAGE CAPACITIES IN ACRE-FEET						
			Recommended Project	TWO PURPOSE PROJECTS			SINGLE PURPOSE PROJECTS		
			FC, REC & WQC	REC & WQC	FC & WQC	FC & REC	FC	REC	WQC
Flood Control	4,700	8.2	4,700	-	4,700	4,700	4,700	-	-
Recreation	-	-	-	-	-	3,000	-	3,000	-
Water Quality	3,000	5.2	3,000	3,000	3,000	-	-	-	3,800 (2)
Conservation	700	1.2	700	700	700	-	100	-	700
Total	8,400	14.6	8,400	3,700	8,400	7,700	4,800	3,000	4,500
Full Pool Elev., Ft. - MSL			835	816	835	832.5	821.5	812.5	820.5 (2)

(1) FC = Flood Control; REC = Recreation; WQC = Water Quality Control.

(2) Includes 3,000 a.f. planned at Nookagee Lake and 800 a.f. for Whitmanville Lake.

(1) Flood Control Benefits. - Average annual flood control benefits, adjusted for the growth projected to take place in the basin, are estimated at $730,000. This value is based on Nookagee Lake acting in a system with Whitmanville Lake and Phillips Dam after completion of the downstream channel improvement along the North Nashua River.

(2) Recreation Benefits. - Recreation benefits are based on a net average annual fishery utilization of 11,300 fisherman-days. Total annual recreational benefits are estimated at $34,000.

(3) Water Quality Control Benefits. - Water quality control benefits are estimated on the basis of a single-purpose water quality control dam and reservoir at the Nookagee project site. This represents the most economical alternate in the absence of the project. Total benefits for the North Nashua River Basin water quality control are estimated at $573,000 of which $453,000 (79%) was accredited to Nookagee.

6. Cost Allocations. - Costs to the project purposes were allocated by the Separable-Costs Remaining Benefits method. Table D-6 outlines in detail the cost allocations and Table D-2 summarizes the results of allocation for the recommended project. The total investment includes the first cost plus interest during construction.

TABLE D-2

SUMMARY OF COST ALLOCATIONS

Purpose	First Cost	Total Investment	Annual Charges
Flood Control	$ 5,700,000	$ 6,169,000	$368,000
Recreation	270,000	296,000	23,000
Water Quality Control	4,530,000	4,901,000	297,000
Totals	$10,500,000	$11,366,000	$688,000

7. Comparison of Benefits and Costs. - A comparison of benefits accruing to each project purpose with the costs allocated to the respective purpose indicates that each project purpose is amply justified as shown in Table D-3.

TABLE D-3

ECONOMIC ANALYSIS

Purpose	Annual Benefits	Annual Costs	Benefit-Cost-Ratio
Flood Control	$ 730,000	$ 368,000	1.98
Recreation	34,000	23,000	1.50
Water Quality Control	453,000	297,000	1.52
Totals	$1,217,000	$ 688,000	1.77

8. Apportionment of Costs Among Interests. -

a. Federal. - Flood control and water quality control benefits realized from construction of the recommended project are widespread and payable in full by the Federal Government. Because the project includes only minimum facilities, all costs associated with recreation are the responsibility of the Federal Government.

b. Non-Federal. - There is no financial liability, by non-Federal interests, for the Nookagee Lake Project.

c. Summary of Apportionment of Costs Among Interests. - Since all costs are Federal, the apportionment of costs among interests is not necessary.

9. Cost Estimates. - A summary of major construction items together with estimated first costs is given in Table D-5. Also included are estimates of investments, and average annual charges for the recommended three-purpose project, specific and joint-use costs, and separate single-purpose and two-purpose projects computed for cost allocation purposes. The detailed cost allocation is shown in Table D-6.

TABLE D-4

DETAILED COST ESTIMATE
(July 1972 Price Level)

	Description	Quantity	Unit	Unit Price	Estimated Amount
01.	Lands and Damages				
	Lands, Acquisition & Resettlement				$ 1,500,000
02.	Relocations				
	Roads	1	Job	L.S.	1,143,000
	Telephone	1	Job	L.S.	53,600
	Electric	1	Job	L.S.	29,000
	Sub-Total				1,225,600
	Contingencies				184,400
	TOTAL RELOCATIONS				$ 1,410,000
03.	Reservoir				
	Log Boom	1	Job	L.S.	$ 10,000
	Reservoir Clearing	175	Ac.	$900	157,500
	Grubbing & Stripping	166	Ac.	$2,400	398,400
	Contingencies				84,100
	TOTAL RESERVOIR				$ 650,000
04.	Dam				
	Preparation of Site	1	Job	L.S.	$ 15,000
	River Diversion	1	Job	L.S.	10,000
	Control of Waters	1	Job	L.S.	95,000
	Unclassified Excavation General	293,000	C.Y.	$1.00	293,000
	Unclassified Excavation Borrow	1,160,000	C.Y.	$1.30	1,508,000
	Rock Excavation - Open Cut	56,000	C.Y.	$4.20	235,200
	Hand Cleaned Bedrock Surface	100	Sq.	$35.00	3,500

TABLE D-4 (Continued)

Description	Quantity	Unit	Unit Price	Estimated Amount
04. Dam				
Compacted Impervious Fill	720,000	C.Y.	$ .40	$ 288,000
Compacted Random Fill	370,000	C.Y.	.40	148,000
Compacted Pervious Fill	77,000	C.Y.	.40	30,800
Backfill Gravel	3,000	C.Y.	6.50	19,500
Compacted Drainage Fill	86,000	C.Y.	5.00	430,000
Compacted Impervious Backfill	8,000	C.Y.	6.00	48,000
Road Gravel	3,700	C.Y.	3.20	11,840
Gravel Bedding	55,000	C.Y.	2.00	110,000
Spoil Fill	12,000	C.Y.	.40	4,800
Uncompacted Impervious Fill	24,000	C.Y.	.20	4,800
Additional Embankment Rolling	200	Hrs.	30.00	6,000
Rock Protection	68,000	C.Y.	3.10	210,800
Foundation Grouting	1	Job	L.S.	25,000
Concrete - Walls & Weir	1,830	C.Y.	75.00	137,250
Concrete - Spillway Lining	570	C.Y.	90.00	51,300
Concrete Intake Tower to El. 845	1,020	C.Y.	80.00	81,600
Concrete Intake Tower above El. 845	80	C.Y.	180.00	14,400
Concete - Inlet Structure	140	C.Y.	90.00	12,600
Concrete - Stilling Basin	230	C.Y.	90.00	20,700
Concrete - Transition & Conduit	1,140	C.Y.	90.00	102,600
Concrete - Bridge Abutment & Piers	490	C.Y.	75.00	36,750
Concrete - Service Bridge Deck	90	C.Y.	110.00	9,900
Cement	8,400	Bbl.	6.50	54,600
Steel Reinforcement	330,000	Lbs.	.25	82,500
Rubber Water Stop	400	L.F.	5.00	2,000
Anchors	130	ea.	50.00	6,500
Structural Steel - Misc.	7,000	Lbs.	.60	4,200
Structural Steel Service Bridge	1	Job	L.S.	75,000
Aluminum	8,800	Lbs.	3.00	26,400
Misc. Metals	8,000	Lbs.	2.00	16,000
Intake Tower - Superstructure	1	Job	L.S.	5,000
Gate Vent System	1	Job	L.S.	10,000
Float Well & Accessories	1	Job	L.S.	6,000
Heating & Ventilating System	1	Job	L.S.	4,000
Hydraulic Gates & Machinery	1	Job	L.S.	70,000
Emergency Stop Gate	1	Job	L.S.	10,000
Elevator	1	Job	L.S.	25,000
Water Quality System Pipes and Gates	1	Job	L.S.	30,000
Crane and Hoist	1	Job	L.S.	5,000

TABLE D-4 (Continued)

	Description	Quantity	Unit	Unit Price	Estimated Amount
04.	Dam				
	Diesel Engine	1	Job	L.S.	$ 6,000
	Sump Pump	1	Job	L.S.	2,000
	Electric Work	1	Job	L.S.	25,000
	Tile Gage	1	Job	L.S.	2,000
	4' Chain Link Fence	1,300	L.F.	4.00	5,200
	18' Double Swing Gate	1	Ea.	400.00	400
	Topsoiling	4,000	C.Y.	7.00	28,000
	Seeding	5	Ac.	800.00	4,000
	Guide Rail	4,000	L.F.	3.00	12,000
	Sub-Total				4,481,140
	Contingencies (15%)				668,860
	TOTAL DAM				$5,150,000
08.	Roads				
	Roads	1	Job	L.S.	4,300
	Contingencies				700
	TOTAL ROADS				$ 5,000
14.	Recreation Facilities				
	Recreation	1	Job	L.S.	13,000
	Contingencies				2,000
	TOTAL RECREATION FACILITIES				$ 15,000
19.	Building, Grounds and Utilities				
	Bldg., Grounds & Util.	1	Job	L.S.	113,000
	Contingencies				17,000
	TOTAL BUILDING, GROUNDS & UTILITIES				$ 130,000

TABLE D-4 (Continued)

	Description	Quantity	Unit	Unit Price	Estimated Amount
20.	Permanent Operating Equipment				
	Perm. Oper. Equipment	1	Job	L.S.	$ 52,000
	Contingencies				8,000
	TOTAL PERMANENT OPERATING EQUIPMENT				$ 60,000
30.	Engineering & Design				$ 910,000
31.	Supervision & Administration				$ 670,000
	TOTAL PROJECT FIRST COST				$10,500,000

TABLE D-5

SUMMARY OF CONSTRUCTION EXPENDITURES AND ANNUAL CHARGES

(In $1,000 - July 1972 Price Level)

Project Features	RECOMMENDED MULTIPLE-PURPOSE PROJECT					ALTERNATIVE TWO-PURPOSE PROJECTS			ALTERNATIVE SINGLE-PURPOSE PROJECTS		
	Specific Costs										
	Flood Control	Recreation	Water Quality Control	Joint-Use Costs	Total Costs	Recreation Water Quality	Flood Control Water Quality	Flood Control Recreation	Flood Control	Recreation	Water Quality Control
Lands & Damages				1,500	1,500	950	1,500	1,400	1,150	850	79% of total
Relocations				1,410	1,410	1,380	1,410	1,410	1,390	1,360	
Reservoir			500	150	650	640	650	150	33	120	cost of Single-
Dam				5,150	5,150	3,510	5,150	4,950	4,040	3,050	
Roads				5	5	5	5	5	5	5	Purpose Hookagee
Recreation Facilities		15			15	15	0	15	0	15	
Bldgs., Grounds & Utils.				130	130	130	130	80	80	80	Project
Permanent Operating Equip.			20	40	60	50	60	40	40	30	
Engineering & Design		3	60	847	910	755	907	845	726	624	(0.79 x $8,740)
Supervision & Administration		2	40	628	670	545	668	615	536	466	
TOTAL PROJECT FIRST COST	0	$ 20	$ 620	$ 9,860	$10,500	$ 7,980	$10,480	$ 9,510	$ 8,000	$ 6,600	$ 6,900
Construction Period (Years)					3	3	3	3	3	2	3
Spillway Crest Elev., Ft.-MSL					835	816	835	832.5	821.5	812.5	820.5 (1)
Investment & Annual Charges											
Construction Expenditures		20	620	9,860	10,500	7,980	10,480	9,510	8,000	6,600	6,900
Interest During Construction (5%)		2	51	813	866	658	865	785	660	363	569
Total Investment		22	671	10,673	11,366	8,638	11,345	10,295	8,660	6,963	7,469
Annual Charges:											
Int. & Amort. (.055261)		1	37	590	628	477	627	569	479	385	413
Oper. & Maint.	4	5	4	41	54	45	49	48	26	30	37
Major Replacements	1	0	1	4	6	4	6	4	3	2	3
TOTAL ANNUAL CHARGES	5	6	42	635	688	526	682	621	508	417	453

(1) Hookagee Site

TABLE D-6

NOOKAGEE LAKE - COST ALLOCATION
ALLOCATION BY SEPARABLE COSTS-REMAINING BENEFITS METHOD

ITEM	FLOOD CONTROL	WATER SUPPLY	RECREATION	WATER QUALITY CONTROL	NAVIGATION	POWER	TOTAL
A. ALLOCATION OF ANNUAL COSTS-							
1. BENEFITS	730000.	0.	34000.	453000.	0.	0.	1217000.
2. ALTERNATE COSTS	508000.	0.	417000.	453000.	0.	0.	1378000.
3. BENEFITS LIMITED BY ALTERNATE COST	508000.	0.	34000.	453000.	0.	0.	995000.
4. SEPARABLE COST	162000.	0.	6000.	67000.	0.	0.	235000.
5. REMAINING BENEFITS	346000.	0.	28000.	386000.	0.	0.	760000.
6. RATIO OF REMAINING BENEFITS -	45.526	0.000	3.684	50.789	0.000	0.000	100.000
7. ALLOCATED JOINT COSTS	206234.	0.	16689.	230076.	0.	0.	453000.
8. TOTAL ALLOCATION, PROJECT COST	368234.	0.	22689.	297076.	0.	0.	688000.
B. ALLOCATION OF LOSS OF PRODUCTIVITY							
1. SEPARABLE COSTS	0.	0.	0.	0.	0.	0.	0.
2. ALLOCATED JOINT COSTS	0.	0.	0.	0.	0.	0.	0.
3. TOTAL ALLOCATIONS	0.	0.	0.	0.	0.	0.	0.
C. ALLOCATION OF OPERATION + MAINTENANCE							
1. SEPARABLE COSTS	9000.	0.	5000.	6000.	0.	0.	20000.
2. ALLOCATED JOINT COSTS	15479.	0.	1253.	17268.	0.	0.	34000.
3. TOTAL ALLOCATION	24479.	0.	6253.	23268.	0.	0.	54000.
4. SPECIFIC COSTS	4000.	0.	5000.	4000.	0.	0.	13000.
5. ALLOCATED JOINT-USE COSTS	20479.	0.	1253.	19268.	0.	0.	41000.
6. RATIO FOR ALLOC OF JOINT-USE COSTS	49.949	0.000	3.055	46.996	0.000	0.000	100.000
D. ALLOCATION OF MAJOR REPLACEMENTS							
1. SEPARABLE COSTS	2000.	0.	0.	2000.	0.	0.	4000.
2. ALLOCATED JOINT COSTS	911.	0.	74.	1016.	0.	0.	2000.
3. TOTAL ALLOCATIONS	2911.	0.	74.	3016.	0.	0.	6000.
4. SPECIFIC COSTS	1000.	0.	0.	1000.	0.	0.	2000.
5. ALLOCATED JOINT-USE COSTS	1911.	0.	74.	2016.	0.	0.	4000.
E. ALLOCATION OF INVESTMENT + FIRST COST							
1. ANNUAL INVESTMENT	340845.	0.	16363.	270792.	0.	0.	628000.
2. ALLOCATED INVESTMENT	6168856.	0.	296152.	4900992.	0.	0.	11366000.
3. RATIO OF ALLOCATED ANNUAL INVEST. -	54.275	0.000	2.606	43.120	0.000	0.000	100.000
4. INITIAL CONSTRUCTION EXPENDITURE	5698837.	0.	273588.	4527575.	0.	0.	10500000.
F. ALLOCATION OF CONSTRUCTION EXPENDITURE							
1. SPECIFIC INVESTMENT	0.	0.	22000.	671000.	0.	0.	693000.
2. INVESTMENT IN JOINT-USE FACILITIES	6168856.	0.	274152.	4229992.	0.	0.	10673000.
3. INTEREST DURING CONST, JOINT-USE FAC.	469903.	0.	20883.	322213.	0.	0.	813000.
4. CONST. EXPENDITURE IN JOINT-USE FAC.	5698952.	0.	253269.	3907779.	0.	0.	9860000.
5. RATIO OF CONST. EXP. IN JOINT-USE FAC.	57.799	0.000	2.569	39.633	0.000	0.000	100.000
6. CONST. EXPENDITURE IN SPECIFIC COSTS	0.	0.	20000.	620000.	0.	0.	640000.
7. TOTAL CONSTRUCTION EXPENDITURES	5698952.	0.	273269.	4527779.	0.	0.	10500000.
G. SUMMARY							
1. TOTAL CONST. EXPENDITURES (ROUNDED)	5700000.	0.	270000.	4530000.	0.	0.	10500000.
2. ANNUAL COSTS	368234.	0.	22689.	297076.	0.	0.	688000.
3. ANNUAL BENEFITS -	730000.	0.	34000.	453000.	0.	0.	1217000.
4. BENEFIT/COST RATIO =	1.98	0.00	1.50	1.52	0.00	0.00	1.77

APPENDIX E

THERMAL SIMULATION ANALYSIS

APPENDIX E

THERMAL SIMULATION AND DENSITY CURRENT ANALYSES

SELECTIVE WITHDRAWAL OUTLET SYSTEM

NOOKAGEE LAKE, MASSACHUSETTS

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APPENDIX E

THERMAL SIMULATION AND DENSITY CURRENT ANALYSES

SELECTIVE WITHDRAWAL OUTLET SYSTEM

NOOKAGEE LAKE, MASSACHUSETTS

1. INTRODUCTION AND PURPOSE

The heat budget and density current analyses presented herein were performed in accordance with the requirements of ETL 1110-2-160, dated 17 November 1972. The objectives of this study are to simulate the thermal stratification which will occur in Nookagee Lake and to develop design criteria for the selective withdrawal outlet system to be included in the project. Design criteria include the capacity and location of the multi-level intakes to meet designated release temperature objectives.

2. PROJECT DESCRIPTION

A general description of Nookagee Lake Project features and description of the Phillips Brook and North Nashua River watersheds are contained in Design Memorandum No. 1, Hydrology (revised). Nookagee Lake conservation storage will contain 3,000 acre-feet for water quality control and 700 acre-feet for combined dead pool and sediment accumulation purposes. Storage space in the amount of 4,700 acre-feet (8.2 inches) is provided for flood control. Area-capacity curves are shown on plate 2-12 of the main section of this General Design Memorandum.

The project will be operated as part of a system which includes the authorized Whitmanville Lake and Phillips Brook Dam Projects to provide low flow augmentation for water quality control and flood control for the principal communities of Fitchburg and Leominster, along the North Nashua River, and other communities.

3. SELECTIVE WITHDRAWAL SYSTEM

In addition to the flood control outlet at the bottom of the intake tower (elevation 753 feet msl), multilevel intakes will

provide the means for selective withdrawal and thus the capability to regulate the physical/chemical quality of releases during periods of lake temperature stratification.

The selective withdrawal system will basically consist of a standpipe (wetwell) located within the interior of the dry flood control tower to which inlets will be connected at elevations determined by this study. Releases will discharge through the standpipe into the flood control conduit at a point downstream from the flood control service gate. A detailed description of the selective withdrawal system will be presented in Design Memorandum No. 9, Hydraulic Analysis.

4. THERMAL SIMULATION ANALYSIS

a. General. The thermal simulation analysis provides the means to design selective withdrawal outlets to meet the water quality objectives of the Nookagee Lake Project. In the analysis, heat budget methods were employed which evaluate the exchange of heat energy within the impoundment over specified intervals of time caused by the following phenomena: thermal energy transfer across the air-water interface; advection of thermal energy by inflow and outflow; and internal thermal energy transfer.

b. Method of Analysis. To accomplish the task of performing the complicated calculations involved in the heat budget analysis, a mathematical model was employed which was developed by Water Resources Engineers, Inc. (WRE) of Walnut Creek, California. A document describing this computer program and entitled, "Application of WRE Reservoir Temperature Simulation Model," (ref. 1) was transmitted to Corps offices nationwide in 1971 by the North Pacific Division, for whom it was developed. The slightly modified version of this model developed by the Water Quality Section staff at the Ohio River Division office in Cincinnati was used in this analysis.

c. Selection of Study Years. The approach taken in this study was to examine the synthesized hydrologic record of Phillips Brook streamflow (described in paragraph 4d) for average and extreme conditions. This was accomplished by performing both high and low flow-duration-frequency analyses for the period from June through September (inclusive) using the synthesized data for the entire record from 1919 through 1969. However, as the corresponding stream

temperature data was only available for the period beginning in 1954 (see paragraph 4d) the three study years, an average runoff year, a dry year and a wet year, had to be chosen from this shorter record. Table I gives a summary of the hydrologic characteristics of the three years selected.

TABLE I

FLOW-DURATION-FREQUENCY DATA
SELECTED STUDY YEARS

Phillips Brook at Nookagee Lake
D.A. = 10.8 Sq. Mi.

	Average	Dry	Wet
Year	1956	1964	1969
Low 60-day mean flow, cfs	1.2	0.2	12.9
Percent chance of non-exceedence	20.8	1.3	94.8
Low 120-day mean flow, cfs	4.6	0.6	16.5
Percent chance of non-exceedence	46.1	1.3	92.8
High 60-day mean flow, cfs	7.7	1.0	25.4
Percent chance of exceedence	50.0	98.2	7.2
High 120-day mean flow, cfs	4.8	0.6	16.7
Percent chance of exceedence	52.0	98.7	7.2

Note: Analyses based on flow data for the 122-day period from June through September for 51 years of record beginning 1919.

d. Preparation of Model Data. Phase I of the WRE Model, The Thermal Model Data File, requires the input of data which is employed to maintain the mass balance and for computing the thermal energy transfer within the impoundment which results from the advection and surface heat exchange processes. The following subparagraphs describe the methods employed in developing these data:

(1) Inflow. As there is no record of streamflow for Phillips Brook, data was synthesized in the same manner reported in Design Memorandum No. 1, Hydrology (revised): daily flow data obtained from the USGS gaging station on nearby Priest Brook (D.A. = 19 sq. mi.) was multiplied by the ratio of drainage areas to develop the inflow to Nookagee Lake for 51 years of record.

(2) Outflow and Storage. Hydrologic routing of daily inflows through storage under simulated operation using planned discharge criteria and storage rule curves was performed to develop the daily outflow and storage data. It was necessary to perform these routings for the entire 51-year record so that storage values on the first day of each study year (1956, 1964 and 1969) would properly reflect antecedent conditions.

(3) Meteorological Data. The first phase of the WRE Model, the Thermal Model Data File, requires data for the basic meteorological parameters affecting the heat transfer process at the air-water interface. In this study five parameters were used: sky cover; wind speed; dry bulb temperature; dew point temperature and atmospheric pressure. Data for these parameters were averaged for each 3-hour time interval and were obtained from the records of the National Weather Service's Windsor Locks weather station located near Hartford, Connecticut. This is the nearest first-order station able to provide data which has prevailing climatology similar to that of the Nookagee Lake Project area. The NWS maintains a first-order station at Boston, which is closer, but it is located directly on the coastline where it is subjected to hydrometeorological conditions greatly influenced by the ocean and thus the data are not representative of climatological conditions inland.

(4) Streamflow Temperature.

(a) Inflow. There are no recorded streamflow temperature data for Phillips Brook with the exception of that collected

by NED on an irregular basis during the low flow period of each year since 1970. The USGS has maintained a temperature record at its streamflow and quality monitoring station on the South Branch Ashuelot River at Webb near Marlborough, New Hampshire since 1954. Comparison of the temperature data recorded at this station with the spot data taken on Phillips Brook for water years 1970 and 1971 resulted in confidence that it would be a good index of the inflow temperature to Nookagee Lake. However, as the South Branch Ashuelot station has a contributing area of 36.0 square miles, compared with 10.8 for the project, a direct transposition of the data was not considered appropriate. Instead, a regression equation was developed which relates air temperature and flow, the independent variables, to daily average streamflow temperature, the dependent variable. Daily average air temperature data for 1956, 1964 and 1969 were taken from the record at Birch Hill Dam in Royalston, Massachusetts (see plate E-1) which is published by the National Weather Service. The following regression equations were developed for the three study years:

Year	Equation
1956	$T_i = 17.9295 + 0.3527\ A_i + 0.1172\ A_{i-1} + 0.2309\ A_{i-2} - 0.0638\ Q_i$
1964	$T_i = 15.8652 + 0.3877\ A_i + 0.1362\ A_{i-1} + 0.2696\ A_{i-2} - 0.0610\ Q_i$
1969	$T_i = 18.3067 + 0.3203\ A_i + 0.0686\ A_{i-1} + 0.3066\ A_{i-2} - 0.0506\ Q_i$

where:

i = Julian day,

T_i = Stream temperature (°F) for day i,

A_i = Average daily air temperature (°F) for day i,

A_{i-1} = Average daily air temperature (°F) for day i-1,

A_{i-2} = Average daily air temperature (°F) for day i-2, and

Q_i = Mean daily discharge (cfs) for day i.

The multiple correlation coefficients and the standard errors of estimate for the three equations are 0.95, 0.94, 0.94 and 3.9, 4.9, 4.1, °F, respectively. Inflow temperature data for Nookagee Lake

was then developed by use of the above equations using the Birch Hill Dam air temperature data but substituting the synthesized flow data for Phillips Brook in place of the South Branch Ashuelot flows. Plate E-2 shows plots of the synthesized stream temperatures for the three study years. These data were used as input to the first phase of the WRE Model for daily average inflow temperature.

(b) Outflow. Harmonic curves were fitted to each of the 3 years of inflow temperature data using the method of least squares. The equations describing these curves are given below:

Year	Equation
1956	$T_i = -14.931 \text{ Sin } (Bi + 62.162) + 49.344$
1964	$T_i = -16.968 \text{ Sin } (Bi + 69.336) + 52.749$
1969	$T_i = -16.272 \text{ Sin } (Bi + 68.247) + 50.509$

where:

i = Julian day,

T_i = Computed stream temperature (curve value) for day i, °F.,

B = 0.9863 angular degrees per day or 0.0172 radians per day.

The harmonic curves generated by these equations represent the natural variation of stream temperature of Phillips Brook for the specified years and are shown on plate E-2.

Representatives of the Massachusetts Department of Natural Resources have indicated acceptance of the natural stream temperature variation as the release temperature objective for operation of the Nookagee Lake Project. The harmonic curve data for the 1956 study year was chosen as representative of the average annual temperature variation of Phillips Brook and was used in the WRE Model as the objective outflow temperature for the three study years.

(5) Selection of Outlet Levels and Capacities. The daily historical routings used to determine the outflow data were also used to evaluate the seasonal pool discharge and drawdown frequencies. This information was used in determining the initial locations of the selective withdrawal outlets and the total project outlet capacity. The seasonal pool drawdown frequency curves are shown on plate E-3. Evaluation of these curves in conjunction with the elevation-capacity curve (plate 2-12 in the main section of this GDM) resulted in the selection of 3 selective withdrawal outlets in addition to the flood control outlet (elevation 753.0 feet msl) for input to the WRE Model. These were located at centerline elevations 781.0, 793.0 and 805.0 feet msl.

The capacity of each selective withdrawal outlet was based on the thesis that the quality of releases could be controlled even during minor flood events that do not materially upset the lake's thermal stratification. An evaluation of data resulting from the discharge frequency analysis led to the adoption of a design discharge capacity equal to 110 cfs for each selective withdrawal outlet. This rate of discharge has a 20 percent chance of exceedence and equals a runoff rate from the contributing area of 10 csm. Under normal operating conditions during the period of lake stratification, release rates will generally range from 20 to 30 cfs.

e. Sensitivity Analysis. For phase II of the WRE Model, the actual temperature simulation program, data are required for use in the equations by which the internal energy transfer processes are computed. These data, along with an explanation of how they are used in the model, are described in detail in reference 1.

Three of these are major variables that control the processes for development of the temperature induced density stratification of the proposed impoundment: effective diffusion, D_c; stability, E; and short wave solar energy extinction depth, Z_d. As the thermal simulation of a proposed impoundment is not an exact science, these variables must be estimated for the first trail run and then varied in a response-evaluation process which frequently is termed "sensitivity analysis."

In this study of Nookagee Lake, the sensitivity analysis was performed under the guidance of Messrs. Drummond and Robey of the Ohio River Division Water Quality Section staff. Temperature profiles

measured during calendar years 1970 and 1971 at Littleville Lake, Huntington, Massachusetts, were used as a basis for estimating trial values of these major variables and for comparison of the characteristics of the computed profiles. A series of trials was made with the model using hydrometeorological data for the 1956 study year. In the response-evaluation process, two of the three variables were held constant while varying the third. Trial values of the effective diffusion coefficient varied from 0.05 to 0.10 Kcal m^{-2} sec^{-1} $°C^{-1}$; the stability was varied from 50 x 10^{-8} to 100 x 10^{-8} m^{-1}; while the short wave energy extinction depth was held constant for all trials at 6.1m (20 feet). The result of this sensitivity analysis was the selection of the following values for use in the "production" runs for each of the three study years:

$\frac{D_c}{}$	$\frac{E}{}$	$\frac{Z_d}{}$
0.075	75 x 10^{-8}	6.1

f. Results. The WRE Reservoir Temperature Simulation Model performs the reservoir heat balance for each computational period (3-hour interval in this study) while simultaneously withdrawing the releases from either one outlet or two adjacent outlets to meet the daily objective outflow temperature. For this study, output was prepared at the 4th execution interval (12:00 noon) every 7 days during the period beginning Julian day 121 and ending Julian day 335. Output consisted of the temperature-depth profile of the impoundment, the level(s) of withdrawal and the computed outflow temperature.

Temperature-depth profiles were plotted for selected days in each study year and are shown on plate E-4. They are arranged so as to graphically display the development and breakup periods of thermally induced density stratification. It can be observed from these profiles that thermal stratification at Nookagee Lake will generally begin during late April and extend through the summer months until early fall (September-October) at which time the so-called "fall-turnover" takes place and the lake again becomes isothermal. The largest temperature gradients occur during July with maximum surface temperatures ranging between 75° and 80° F. during July and August. The WRE Model results indicate that maximum hypolimnion temperatures lag the peak surface temperatures by two or three weeks and generally attain values around 55° F. However, during hot, dry years the temperature in this zone can reach as high as 67° F. as evidenced by the 1964 study year results.

The large differences in hydrological and meteorological conditions between the three study years are evidenced by the wide variations in the corresponding temperature-depth profiles for given dates in the low flow season. It is considered that these simulated thermal conditions for Nookagee Lake represent the range of conditions which can reasonably be expected to occur during the project's operational lifetime.

As such, the computed outflow temperatures for the selected study years yield a measure of the project's ability to be operated to meet the designated temperature objective under widely varying hydrometeorological influences. To evaluate this measure of the effectiveness of the proposed outlet arrangement, outflow temperatures for each study year were plotted against the curve of natural annual temperature variation (see paragraph 4d). These plots are shown on plate E-5.

The comparisons show that the computed outflow temperatures fall within a tolerable range around the designated objective temperature curve. Even during the extreme drought year, 1964, the maximum deviation is only 7° F. The results are satisfactory and indicate that the locations of the selective withdrawal outlets at centerline elevations 781.0, 793.0 and 805.0 feet msl provide the means to effectively control releases to meet the designated stream temperature objectives.

5. DENSITY CURRENT ANALYSIS

a. General. The characteristics of flow in a density stratified impoundment differ greatly from those in one which is isotropic. Study of the hydromechanics of flow from stratified reservoirs was made at the Corps' Waterways Experiment Station (WES) and the results were published in WES Technical Report H-69-10 entitled, "Mechanics of Flow from Stratified Reservoirs in the Interest of Water Quality," (reference 2). Basically, the depth and position of the zone of withdrawal and the velocity profile associated with it were found to be a function of the discharge rate and the density gradient.

Having already developed the temperature-depth profiles in the thermal simulation part of this study, the density gradients were therfore known. Thus both the data and methods were available

with which to compare the relationships of withdrawal zones under several different thermal regimes. Evaluation of the depth and positioning of the withdrawal zones provided another measure of the adequacy of the selective withdrawal system to meet water quality management objectives.

b. Procedure. Temperature-depth profiles developed for each study year were reviewed and the profiles for Julian days 182, 196 and 231 were selected for use in the density current analysis. Selection of these profiles was based primarily on the fact that they exhibit large temperature gradients (with the exception of day 231 in 1964) and occur during the July-August period when attainment of water quality management objectives is most critical.

For development of the withdrawal zones and velocity profiles, a series of discharge rates were used which ranged from those representative of normal low flow augmentation releases to those associated with the 5-year frequency (stratification period) flood event. Values used in the study were 10, 20, 50, 75 and 110 cubic feet per second.

The temperature-depth profiles and discharges were input to a computer program developed by WES (reference 2) which performed the otherwise arduous task of computing the vertical dimension and position of the withdrawal zones and corresponding velocity profiles by the methods developed in the WES studies of the mechanics of stratified flow. Velocity profiles were computed for each discharge rate at each selective withdrawal outlet and then plotted against the temperature and density profiles for each study day and year.

c. Results. A total of nine density profiles were thus analyzed to demonstrate geometry. The resulting velocity profiles are shown on plates E-6 through E-14, inclusive. The profiles show that the withdrawal zones are coterminous at lower discharges but superpositioning of these zones becomes greater with increasing discharge. This characteristic provides visual indication that operational changes can be accomplished from one withdrawal level to another without causing abrupt changes in the downstream environment.

6. CONCLUSIONS

The results of the thermal simulation and density current analyses yield evidence that selective withdrawal outlets located at centerline elevations 781.0, 793.0 and 805.0 feet msl and sized to pass discharges up to 110 cfs will adequately meet the present water quality management objectives for the Nookagee Lake project. Of almost equal importance is the fact that the withdrawal zone characteristics are such that the withdrawal system is adaptable to possible changes in these objectives during the project's operational lifetime.

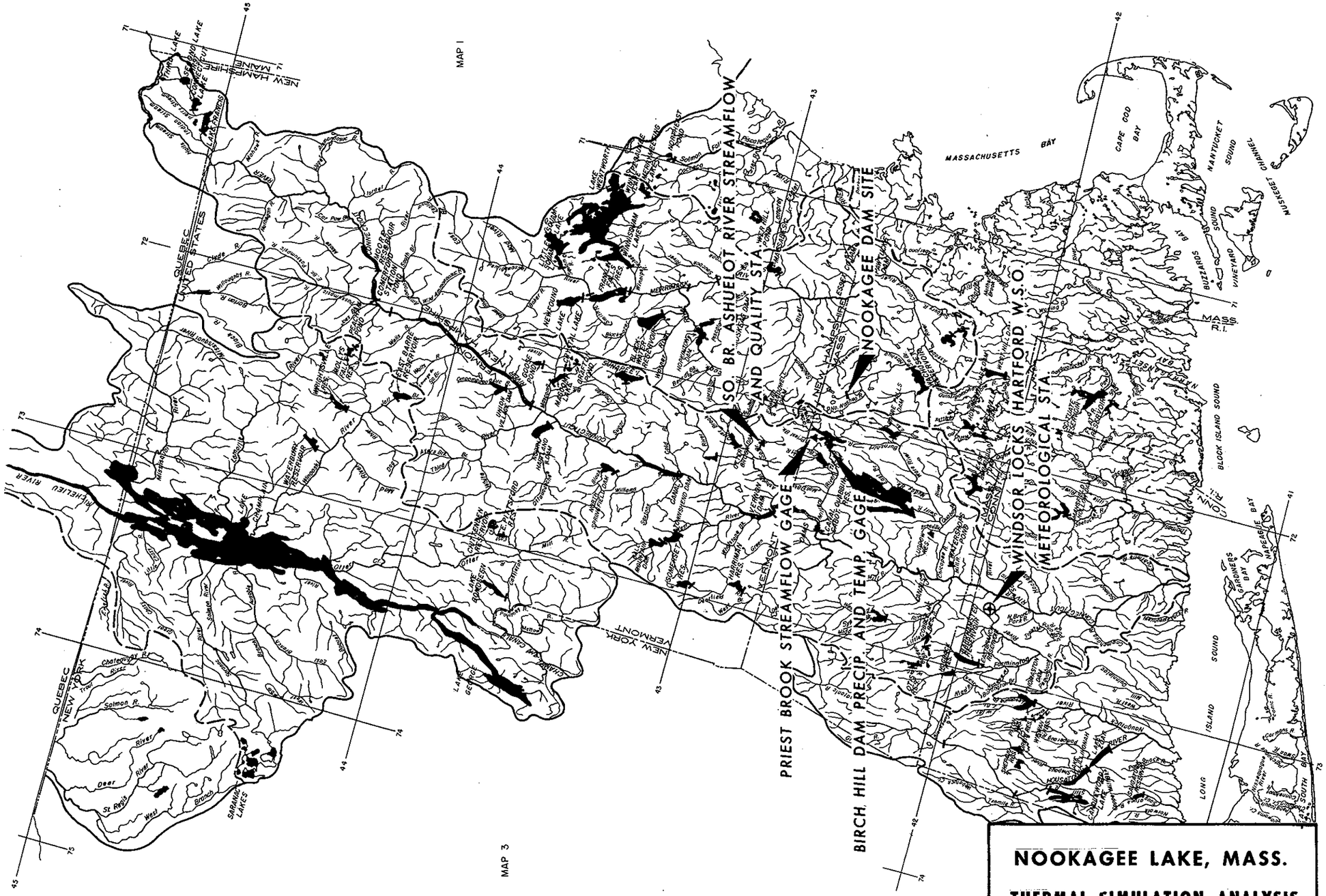
REFERENCES AND SELECTED BIBLIOGRAPHY

1. Bohan, J. P., and Grace, J. L., Jr., "Mechanics of Flow From Stratified Reservoirs in the Interest of Water Quality," Technical Report H-69-10, USAE Waterways Experiment Station, Vicksburg, Mississippi, July 1969.

2. North Pacific Division, Corps of Engineers, "Application of WRE Reservoir Temperature Simulation Model," Portland, Oregon, September 1970.

3. Burdick, J. Clement, III, and Parker, Frank L., "Estimation of Water Quality in a New Reservoir," Report Number 8, School of Engineering, Vanderbilt University and U.S. Army Corps of Engineers, December 1971.

4. U.S. Army Corps of Engineers, Engineering Technical Letter 1110-2-160, "Hydrologic Investigation Requirements for Water Quality Control," 17 November 1972.



NOOKAGEE LAKE, MASS.

THERMAL SIMULATION ANALYSIS

BASIC DATA STATIONS

PLATE E-1

(2) Revised 1960

CORPS OF ENGINEERS — U. S. ARMY

NOOKAGEE LAKE COMPUTED INFLOW-TEMPERATURE

1956

$T_I = -14.931\ Sin\ (Bi + 62.162) + 49.344$

1954

$T_I = -16.969\ Sin\ (Bi + 69.336) + 52.749$

1953

$T_I = -16.272\ Sin\ (Bi + 68.247) + 50.309$

JULIAN DAY: 0, 50, 100, 150, 200, 250, 300, 365

TEMPERATURE - DEGREES FAHRENHEIT: 30, 40, 50, 60, 70, 80, 90, 100

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

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APPROVAL RECOMMENDED:

CHIEF, TECH. EVALUATION BRANCH

REVIEWED:

PROJECT ENGINEER

APPROVED: DATE:

CHIEF, ENGINEERING DIVISION

SCALE: SPEC. NO.

DRAWING NUMBER:

SHEET

NOOKAGEE LAKE, MASS.
THERMAL SIMULATION ANALYSIS
COMPUTED INFLOW TEMPERATURE AND NATURAL STREAM TEMPERATURE VARIATION

PLATE E-2

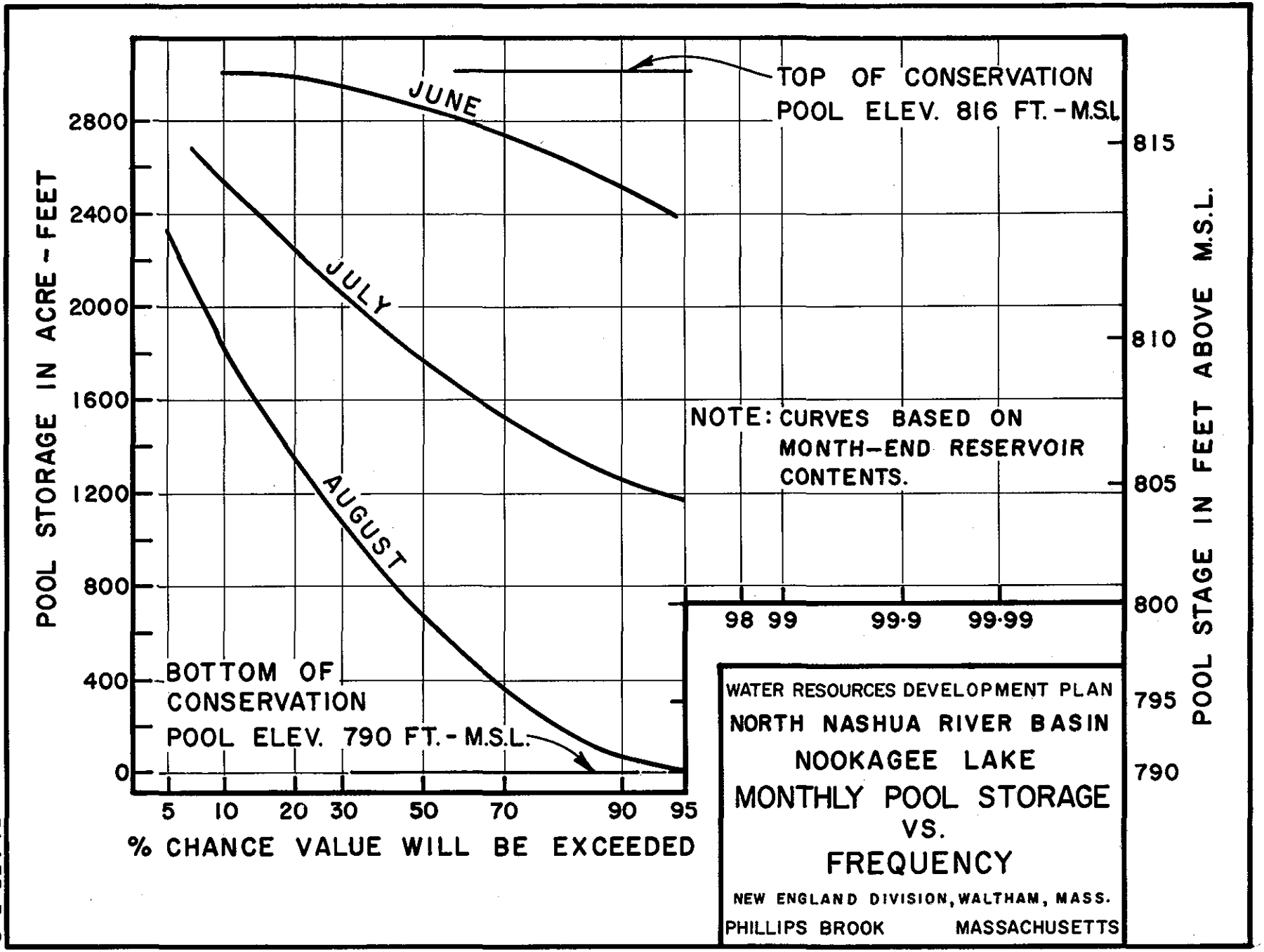
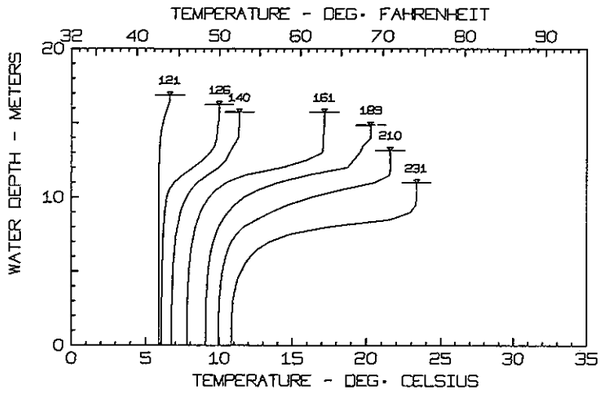
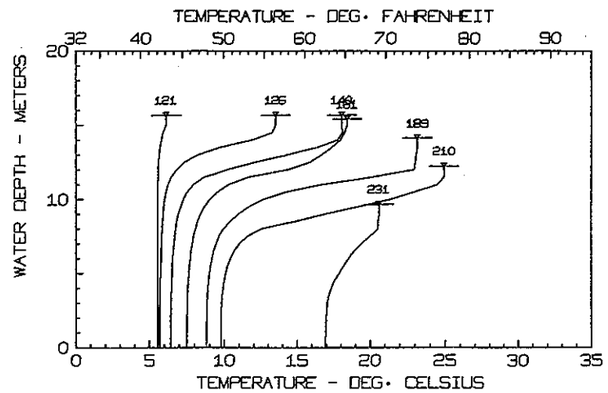
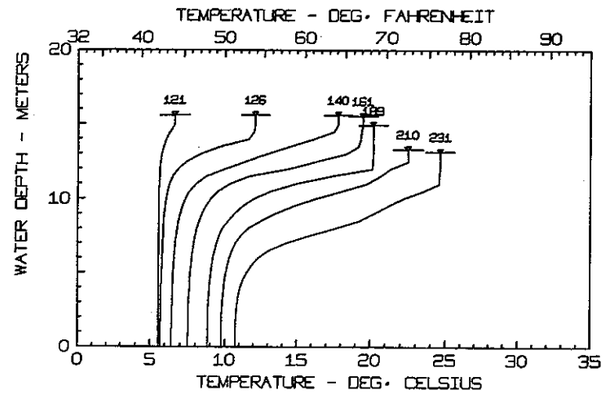
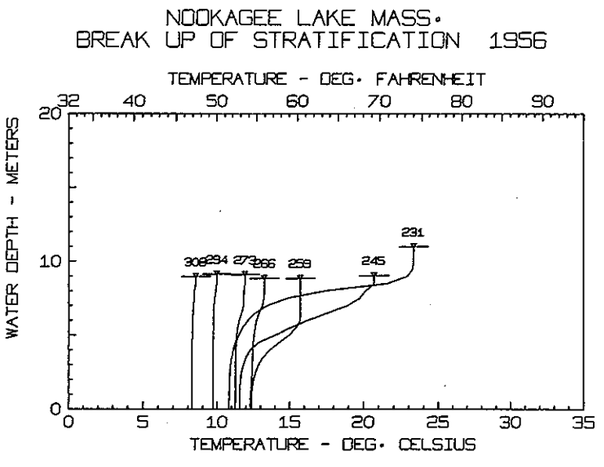

POOL STORAGE IN ACRE-FEET
2800
2400
2000
1600
1200
800
400
0
JUNE
JULY
AUGUST
TOP OF CONSERVATION
POOL ELEV. 816 FT.-M.S.L.
NOTE: CURVES BASED ON MONTH-END RESERVOIR CONTENTS.
BOTTOM OF CONSERVATION POOL ELEV. 790 FT.-M.S.L.
5 10 20 30 50 70 90 95
98 99 99·9 99·99
% CHANCE VALUE WILL BE EXCEEDED
815
810
805
800
795
790
POOL STAGE IN FEET ABOVE M.S.L.
WATER RESOURCES DEVELOPMENT PLAN
NORTH NASHUA RIVER BASIN
NOOKAGEE LAKE
MONTHLY POOL STORAGE
VS.
FREQUENCY
NEW ENGLAND DIVISION, WALTHAM, MASS.
PHILLIPS BROOK MASSACHUSETTS

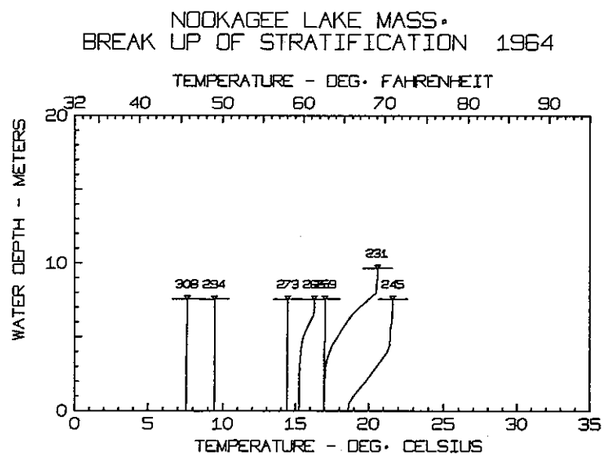
PLATE E-3

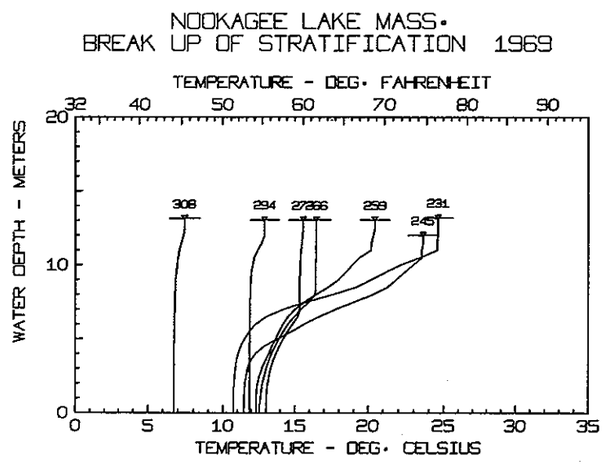












DEVELOPMENT AND BREAK-UP OF STRATIFICATION

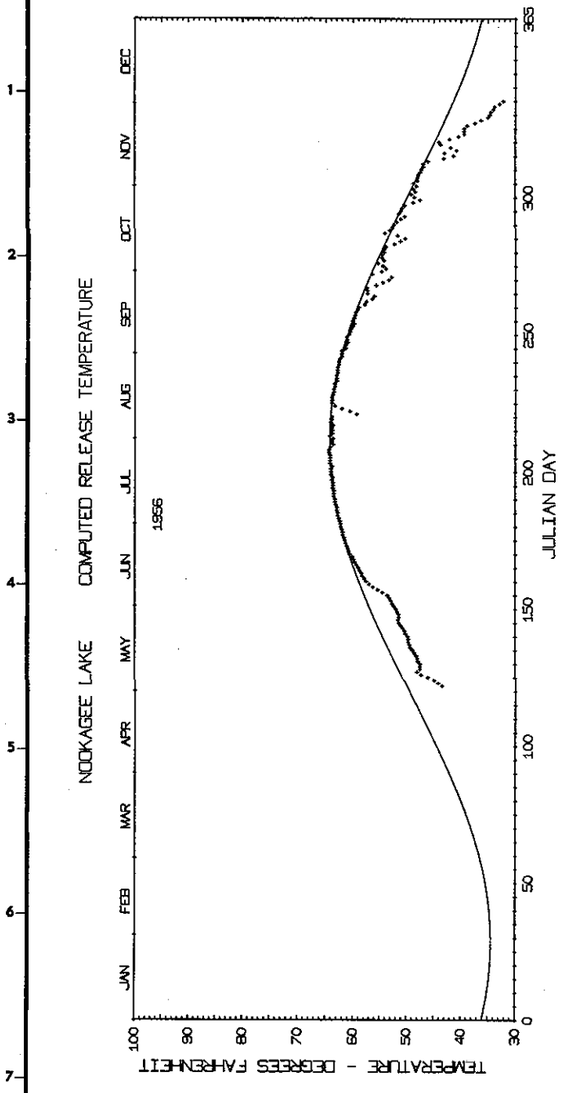
NOOKAGEE LAKE MASSACHUSETTS

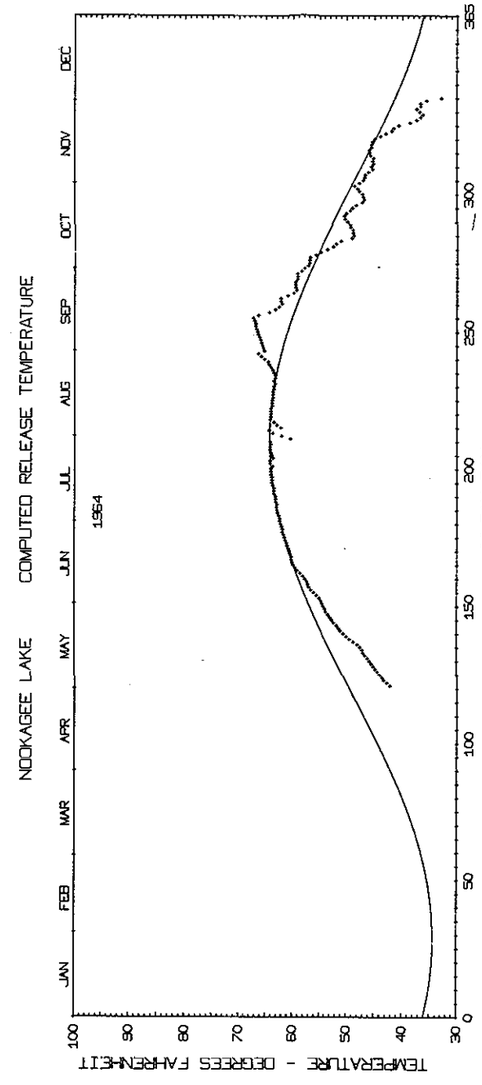
THERMAL SIMULATION STUDY

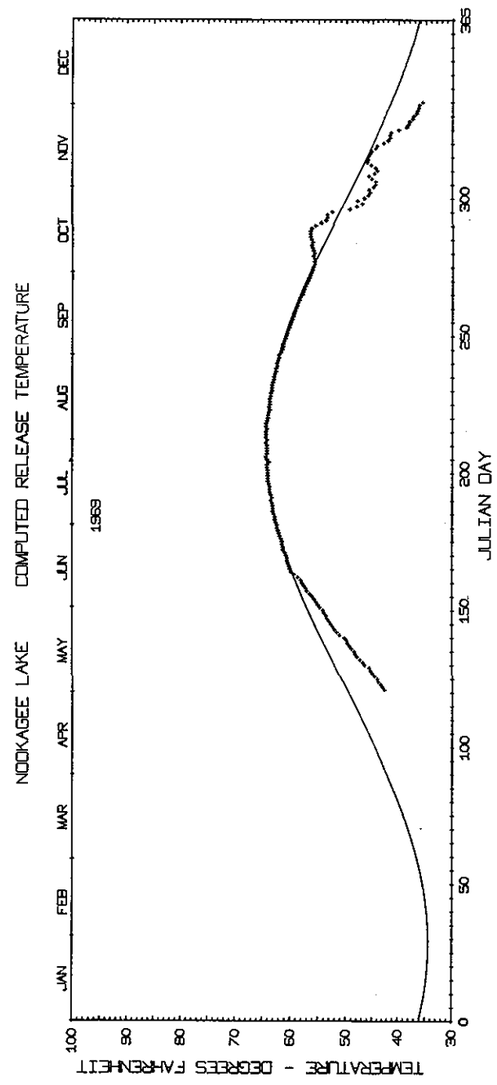
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

PLATE E-4

CORPS OF ENGINEERS — U. S. ARMY







GRAPHIC SCALE

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REVIEWED:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:		
CHIEF BRANCH		

NOOKAGEE LAKE, MASS.
THERMAL SIMULATION ANALYSIS
NATURAL OUTFLOW TEMPERATURE OBJECTIVE

APPROVED _____ DATE _____
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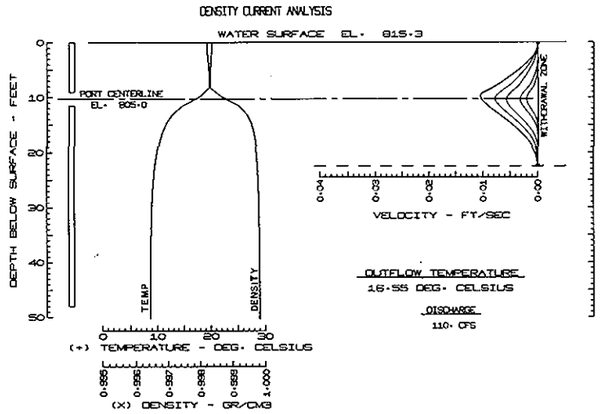
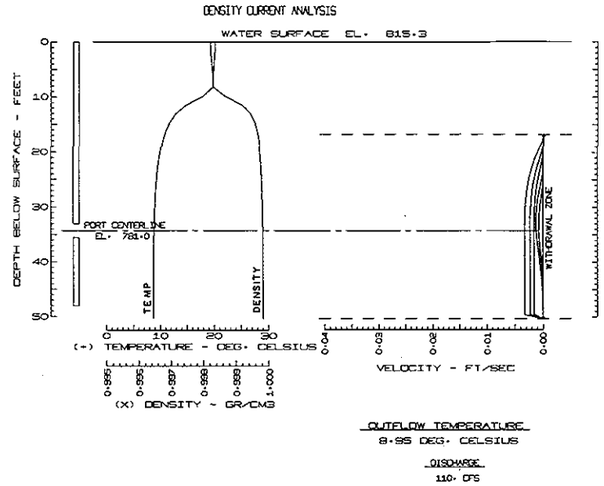
PLATE E-5

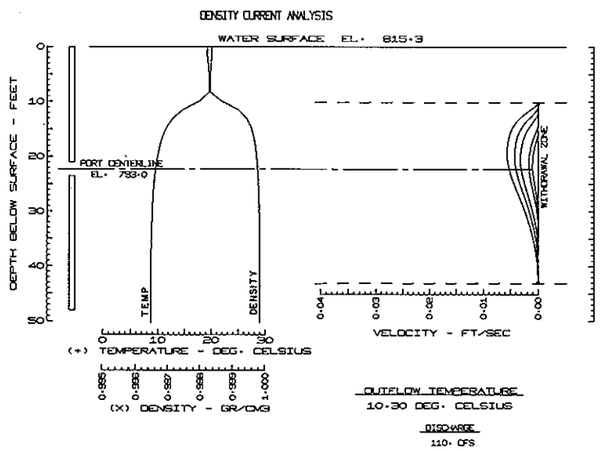
CORPS OF ENGINEERS — U. S. ARMY

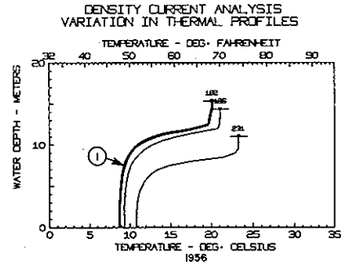


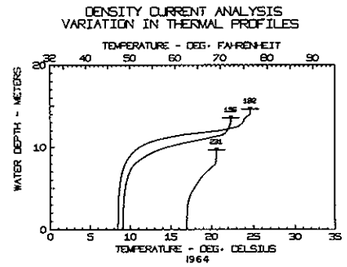


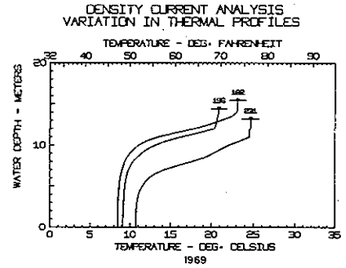
GENERAL NOTE:

Velocity profiles shown are identified in order of decreasing width of the withdrawal zones for discharges of 110, 75, 50, 20, and 10 cubic feet per second, respectively.









AVERAGE RUNOFF YEAR-1956

JULIAN DAY 182

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CORPS OF ENGINEERS
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SUBMITTED

CHIEF, SECTION

APPROVAL RECOMMENDED

CHIEF, BRANCH

REVIEWED

PROJECT ENGINEER

APPROVED — DATE

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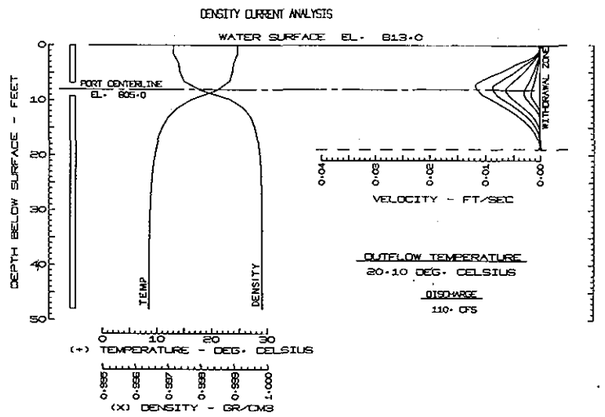
SCALE | SPEC. NO.

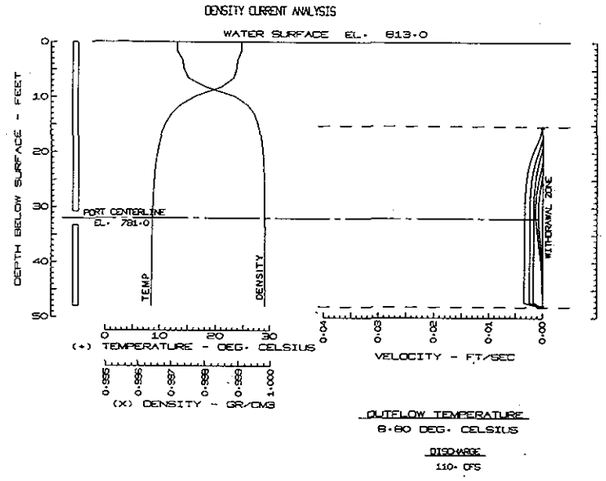
DRAWING NUMBER

NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 1

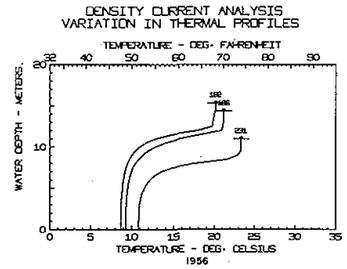
PLATE E-6

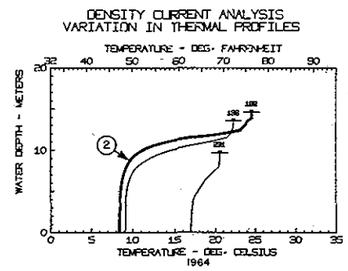
CORPS OF ENGINEERS — U. S. ARMY

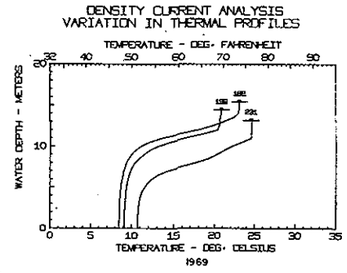


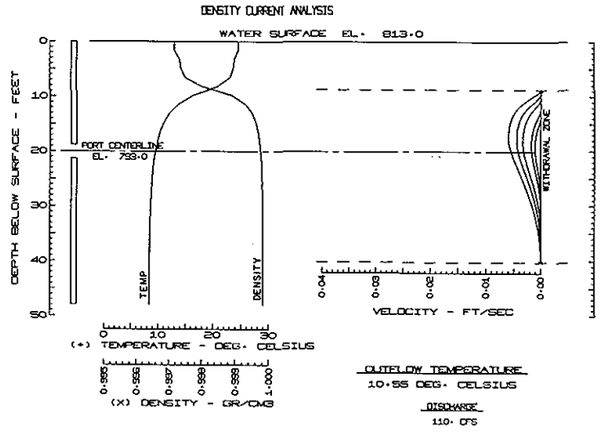


NOTE:
See general note on Profile No. 1









DRY YEAR 1964
JULIAN DAY 182

REVISION	DATE	DESCRIPTION	BY

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WALTHAM, MASS.

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APPROVAL RECOMMENDED
CHIEF, BRANCH
REVIEWED
PROJECT ENGINEER

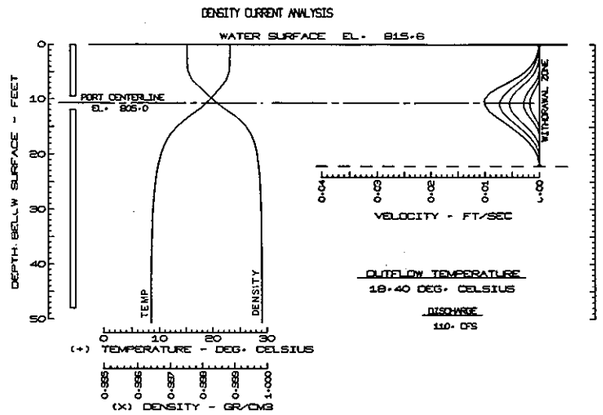
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 2

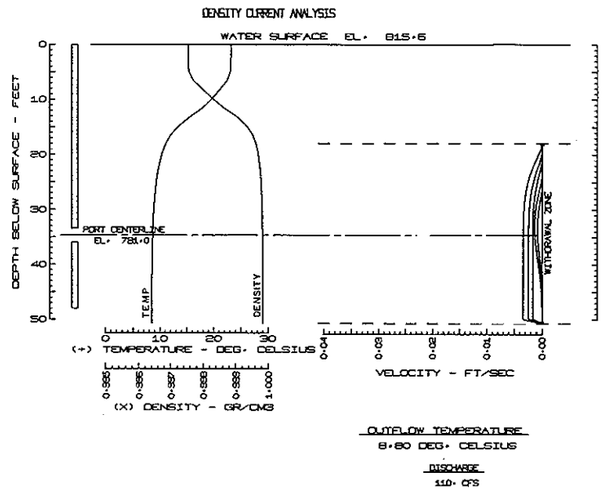
APPROVED
CHIEF, ENGINEERING DIVISION
DATE

SCALE | SPEC. NO.
DRAWING NUMBER

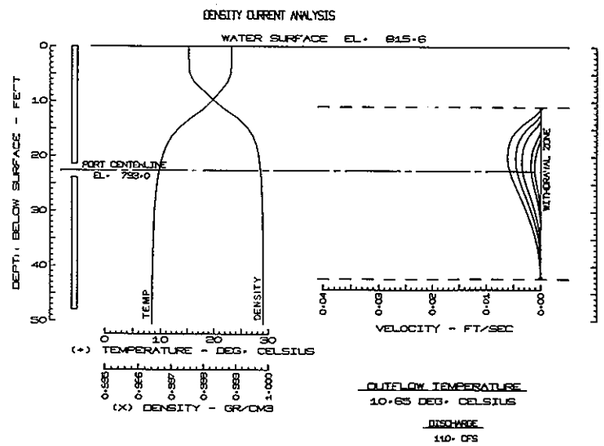
PLATE E-7

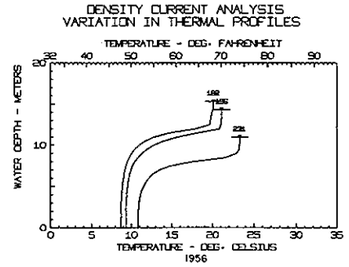
CORPS OF ENGINEERS — U. S. ARMY

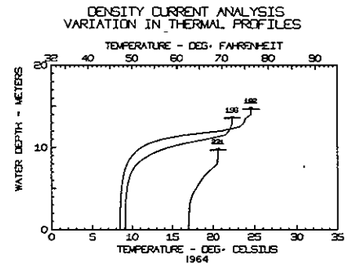


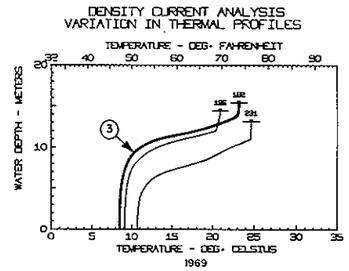


NOTE:
See general note on Profile No. 1









WET YEAR-1969
JULIAN DAY 182

REVISION	DATE	DESCRIPTION	BY

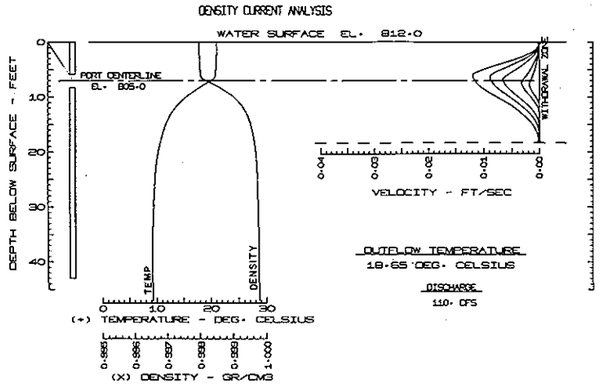
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

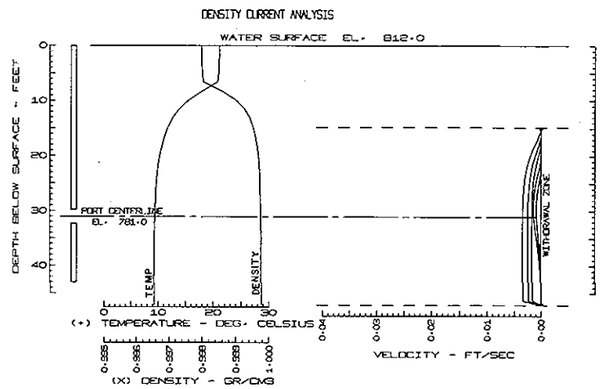
DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVED — DATE
CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO. | DRAWING NUMBER

NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 3

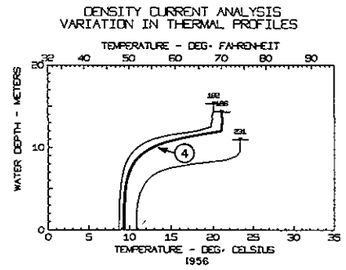
PLATE E-8

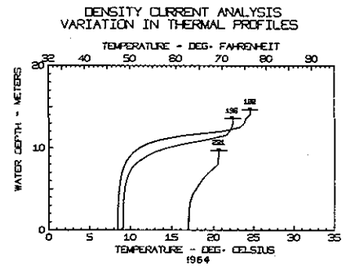
CORPS OF ENGINEERS U. S. ARMY

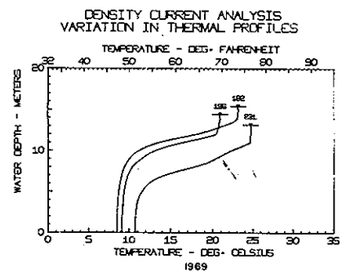




NOTE:
See general note on Profile No. 1







AVERAGE RUNOFF YEAR-1956
JULIAN DAY 196

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF SECTION
APPROVAL RECOMMENDED:
CHIEF BRANCH
REVIEWED:
PROJECT ENGINEER

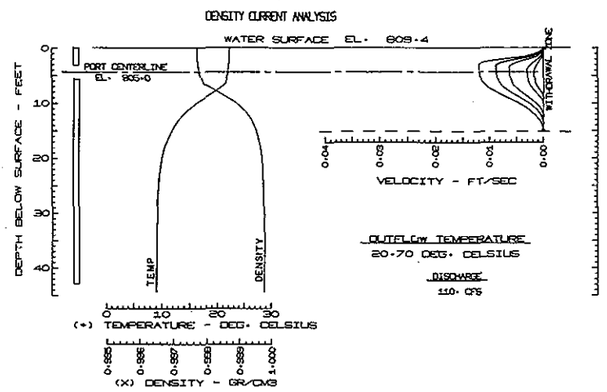
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 4

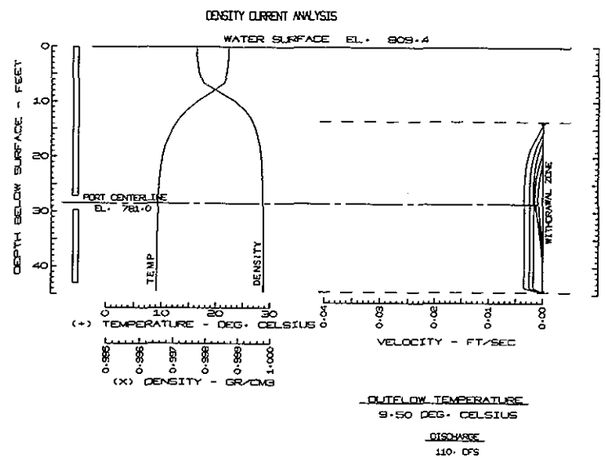
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER

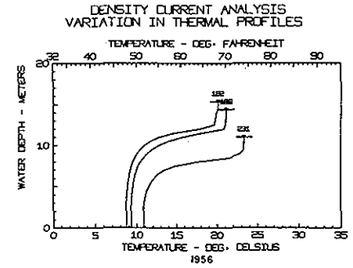
PLATE E-9

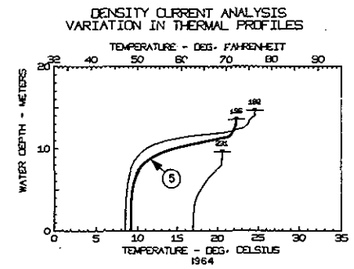
CORPS OF ENGINEERS — U. S. ARMY

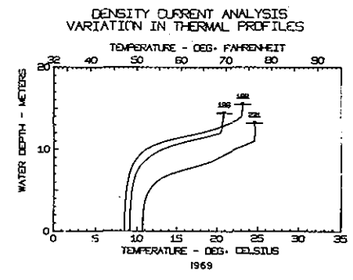


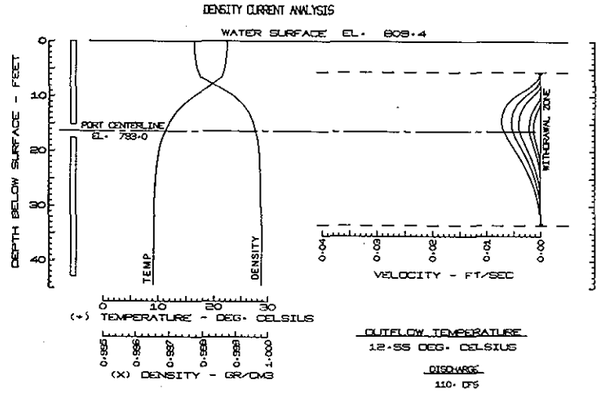


NOTE:
See general note on Profile No. 1









DRY YEAR-1964
JULIAN DAY 196

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

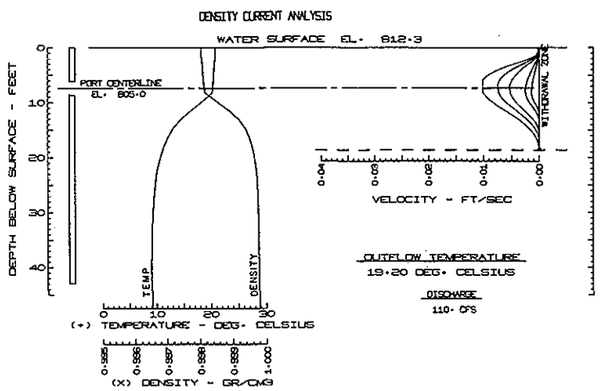
DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVED — DATE
CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO.
DRAWING NUMBER

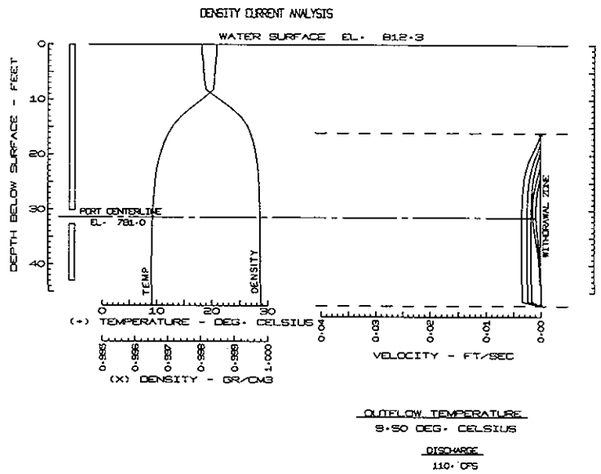
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 5

PLATE E-10

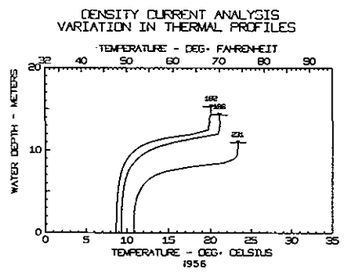
CORPS OF ENGINEERS

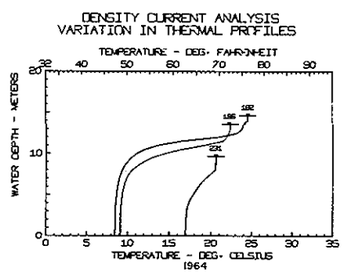
U. S. ARMY

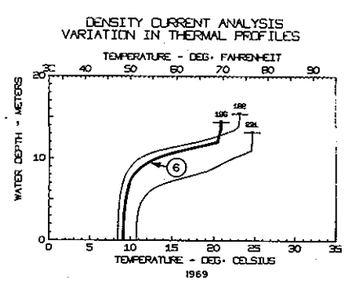




NOTE:
See general note on Profile No. 1







WET YEAR-1969
JULIAN DAY 196

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, BRANCH
REVIEWED:
PROJECT ENGINEER

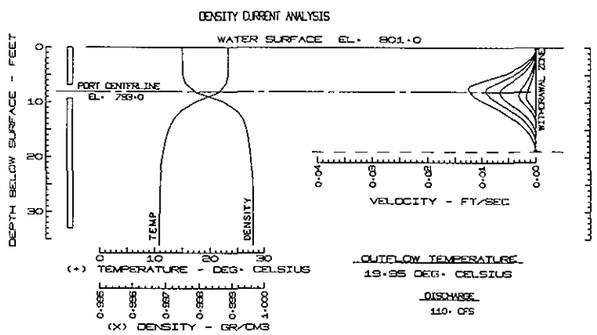
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 6

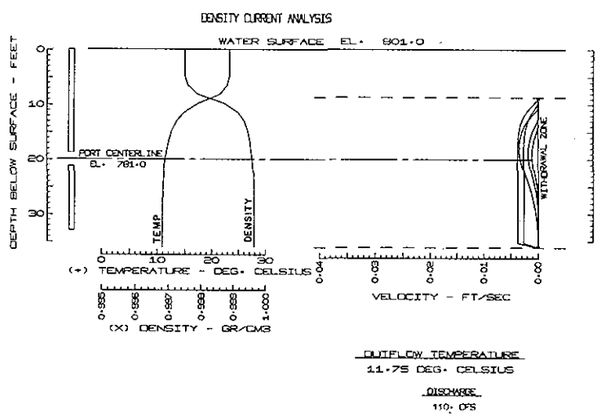
APPROVED
DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER

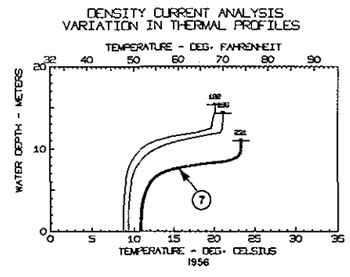
PLATE E-11

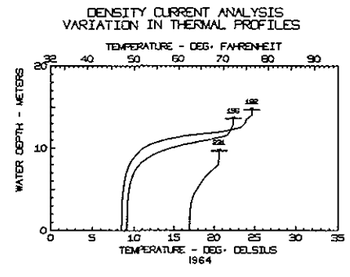
CORPS OF ENGINEERS U. S. ARMY

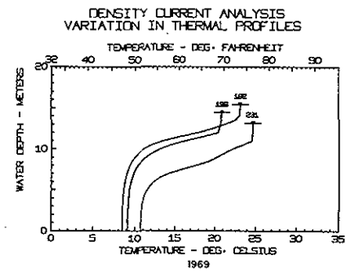




NOTE:
See general note on Profile No. 1







AVERAGE RUNOFF YEAR-1956
JULIAN DAY 231

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

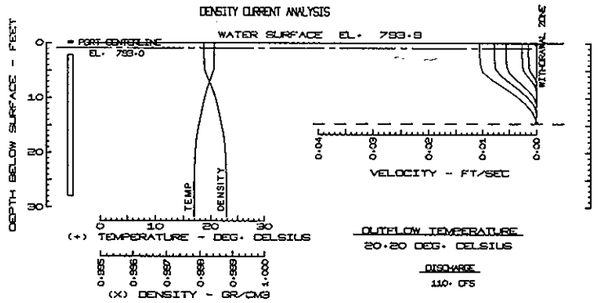
DES. BY | DR. BY | CK. BY
SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, BRANCH
REVIEWED
PROJECT ENGINEER

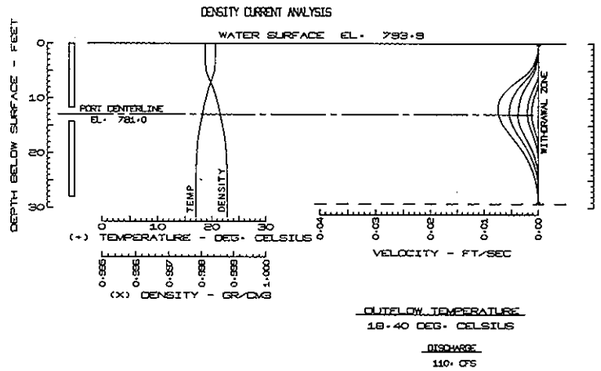
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 7

APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE
SPEC. NO.
DRAWING NUMBER

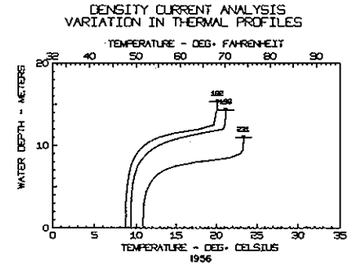
PLATE E-12

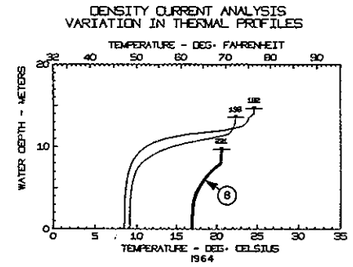
CORPS OF ENGINEERS U. S. ARMY

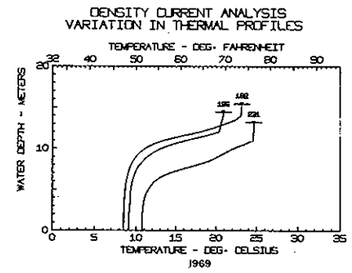




NOTE:
See general note on Profile No. 1







DRY YEAR-1964
JULIAN DAY 231

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, BRANCH
REVIEWED:
PROJECT ENGINEER

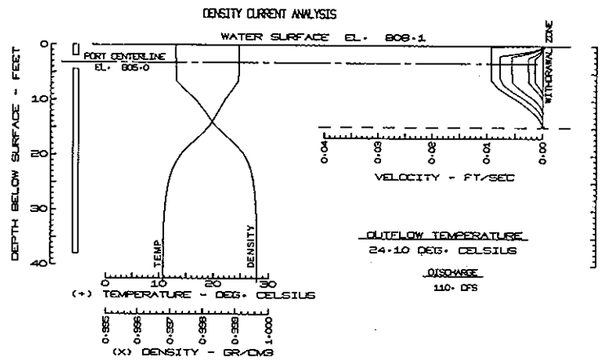
NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 8

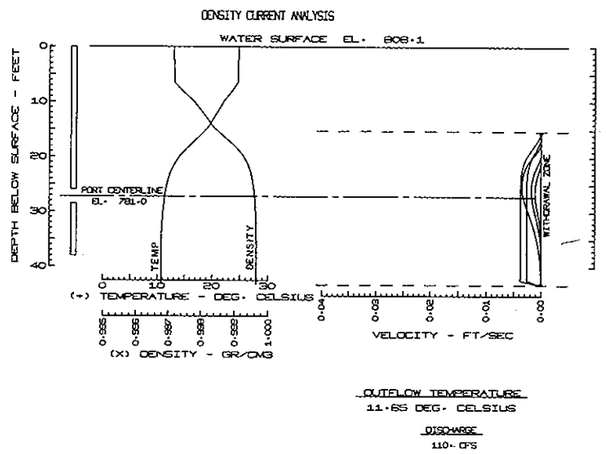
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER

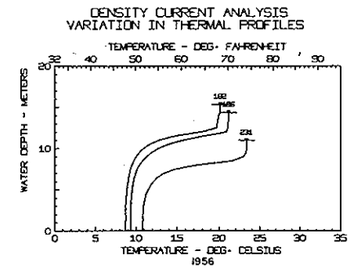
PLATE E-13

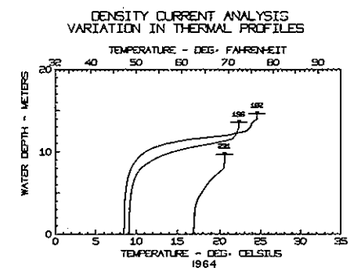
CORPS OF ENGINEERS — U. S. ARMY

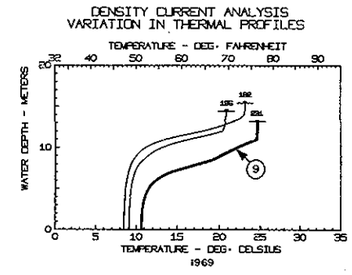




NOTE:
See general note on Profile No. 1







WET YEAR-1969
JULIAN DAY 231

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, BRANCH
REVIEWED:
PROJECT ENGINEER

NOOKAGEE LAKE, MASS.
DENSITY CURRENT ANALYSIS
PROFILE NO. 9

APPROVED
CHIEF, ENGINEERING DIVISION
DATE

SCALE
SPEC. NO.
DRAWING NUMBER

PLATE E-14